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USERS MANUAL FOR THE SATELLITE SURVEILLANCE AVOIDANCE OPTIMIZATION AID

DECISIONS AND DESIGNS INCORPORATED

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USERS MANUAL 78-1-89

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by

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1.0 OVERVIEW

1.1 Introduction

Adversary surveillance has long been a concern of naval commanders at sea. Not only can it identify a naval task force as a possible military target, but it may also lead to an unwanted confrontation with possibly far greater military and political consequences.

Ships at sea are potentially subject to many kinds of surveillance. Traditionally, the important components of a surveillance system have been aircraft, shipping, submarines, land-based radar, and communications sensors. In recent years, however, surveillance systems have added land-based acoustic sensors and earth-orbiting satellites with varied sensing capabilities.

It is possible to avoid some of these surveillance systems by careful pre-transit planning. In many cases, the task force commander may plan to avoid areas of the ocean in which he is likely to be detected by land-based sensors, merchant traffic, aircraft, or submarines. In addition, he may plan to follow a deceptive route so that, if he is detected, his intentions and destination will be difficult to infer. The result of this planning would be a track plan, which consists of a specified transit route. A hypothetical track plan from Norfolk, Virginia, to the Straits of Gibraltar is illustrated in Figure 1-1.

The presence of satellites with surveillance capabilities greatly diminishes the effectiveness of a track plan which

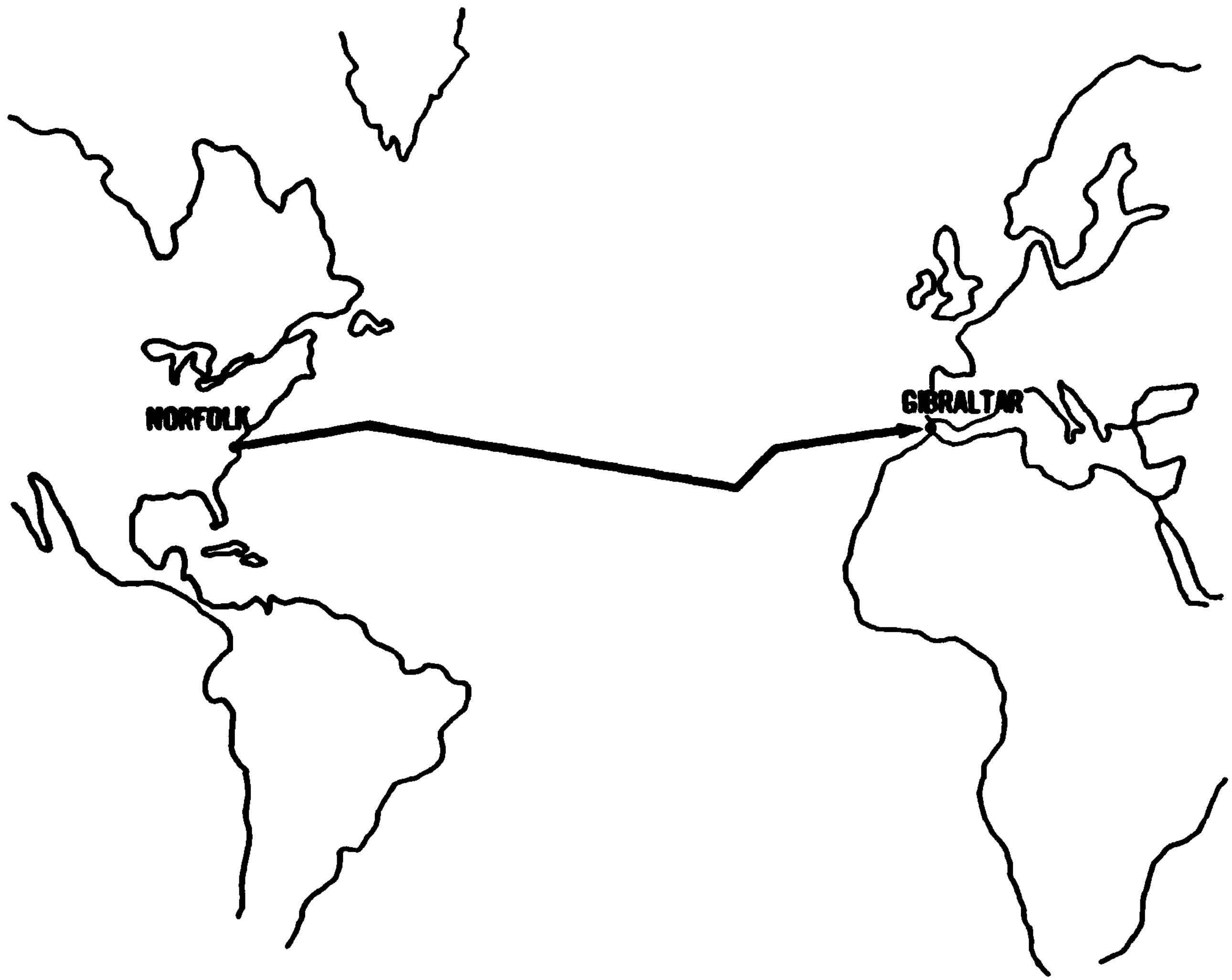


Figure 1-1
A HYPOTHETICAL TRACK PLAN FROM NORFOLK TO GIBRALTAR

is intended to circumnavigate areas of the ocean where surveillance is likely. Since surveillance satellites can cover all areas of the ocean, a track plan by itself would be an ineffective countermeasure for satellite surveillance.

The task force commander can, however, predict a satellite's motion and use that information to his advantage. The ephemeris data for an adversary satellite is either known or can be calculated from observation data. The ground track, which is traced out by movement of the satellite's sub-orbital point across the earth's surface, can then be predicted with precision. The satellite's ground track will usually intersect the commander's track plan at regular, predictable intervals.

One pass of a satellite over the track plan is represented by the ground track segment A in Figure 1-2. The dotted lines on either side of A represent the satellite's effective field of vision. If, at the time of this pass, the task force is in the segment of its track plan within this field of vision, then detection is possible.

As the satellite follows its orbital trajectory, the earth precesses from west to east underneath it. Thus, after one orbital revolution, the same satellite may again cross the track plan with ground track B, which is to the west of A.

A typical non-synchronous satellite with surveillance capabilities normally has an orbital period of about ninety minutes. The time interval between successive detection zones, like those associated with A and B, is roughly equal to one orbital period, depending on the angle of inclination between the ships' track plan and the satellite's ground track. Furthermore, from the vantage point of the task

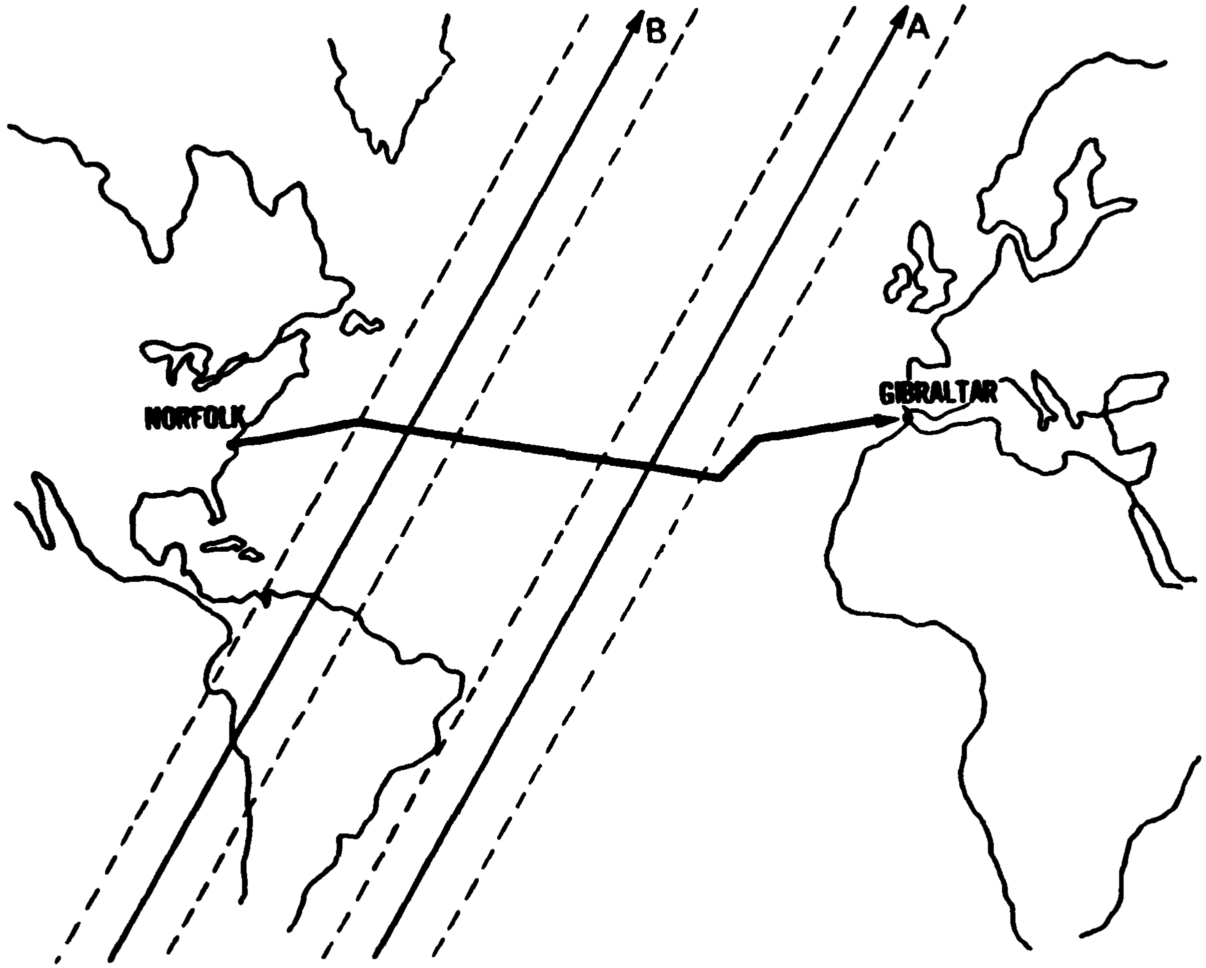


Figure 1-2

TWO SATELLITE PASSES OVER A HYPOTHETICAL TRACK PLAN

force commander, each detection zone lasts for only a few minutes because the satellite moves so quickly; for a satellite having a ninety-minute orbital period and an effective swath diameter of 1,000 nautical miles, the ships' exposure time to surveillance would be less than four minutes.

Thus, each detection zone in Figure 1-2 occurs at a particular time and lasts for only a few minutes. Even if the commander must depart from his origin and arrive at his destination at specified times, he may be able to avoid surveillance from satellite passes A and B entirely by changing his speed of advance (SOA) at appropriate points enroute.

If the transit requires several days, however, a given satellite would normally pass over the track plan many times, and selecting the appropriate SOA to use at various times may become rather complex. The problem is further complicated when there are many surveillance satellites, each with different orbital characteristics and sensing capabilities.

The fact remains that judicious selection of SOA during a transit can minimize the likelihood of detection by hostile surveillance satellites. This report describes a methodology which capitalizes upon the effects of such SOA changes for transit planning. The report also describes a computer decision aid which implements that methodology.

1.2 Generalized Approach

An overview of the Satellite Surveillance Avoidance Aid is shown in Figure 1-3.

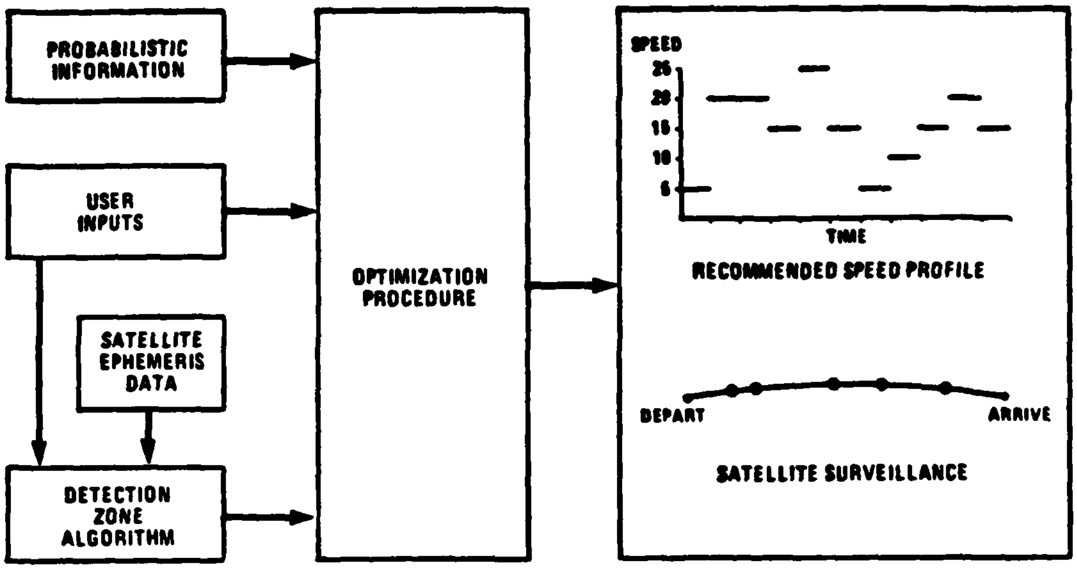


Figure 1-3

AN OVERVIEW OF THE
SATELLITE SURVEILLANCE AVOIDANCE OPTIMIZATION AID

The Aid is designed so that only a small number of parameters is required as user inputs. Important probabilistic information and current satellite ephemeris data are assumed to be supplied through a land-based computer network. Based on inputs from the network and the user, the optimization procedure provides the commander with a recommended SOA profile and all relevant satellite surveillance information.

1.2.1 Optimization procedure - A dynamic program searching over discrete SOA options is used to find a recommended SOA profile through a pattern of detection zones. Since all potential intercepts are not equally important to avoid, a probability model is used to compute the probability of detection within each detection zone, and cost profiles for detection, evasive actions, and speed of advance are obtained from the user. Then, the recommended SOA profile is computed as the one that minimizes the expected cost of the transit.

1.2.2 User inputs - Required user inputs are listed in Figure 1-4. First the user must supply the departure time and arrival time. Ordinarily these parameters are treated as though they were fixed during the optimization process; that is, the optimizer will assume departure is on time and will assure on-time arrival. However, if the user is willing to allow a zero speed of advance as a possibility, the optimizer will suggest that the task force depart late or arrive early if there is any advantage in doing so.

- Departure and arrival times
- Track plan (point of departure, destination, and intermediate points)
- Probability of already being tracked at departure
- SOA options
  (e.g., 5, 10, 15, 20, 25 knots)
- Time increment for SOA changes
  (e.g., 8 hours)
- Fuel costs
- Detection aversion costs
- Evasive action costs

Figure 1-4
USER INPUTS

Next, the departure point, the intermediate points (if any) and the destination are supplied, defining the user's track plan. If no intermediate coordinates are specified, a great circle route is assumed.

Once the track plan specification has been completed, the Aid will ask the user to assess the probability

of already being tracked as he leaves his point of departure. For example, it may normally be the case that adversary ships in the area of the departure point are certain to take notice of his departure. In this case there will be a higher probability that later satellite intersections will result in a detection.

The second phase of the transit plan definition sequence begins with the specification of the SOA options to be considered in the optimization process. The user is asked to do this by providing a minimum value, a maximum value, and an increment. Although the example in Figure 1-4 shows these values to be multiples of 5, this is not a requirement; the only restriction is that the minimum SOA and the maximum SOA must be multiples of the SOA increment. The minimum SOA may in fact be zero or negative.

Following the specification of SOA options, the Aid asks the user to select a time increment to be used in the optimization process as the length of time over which SOA's will be maintained. When a particular SOA value is chosen by the optimizer, the user is expected to maintain that speed for his task force for the duration of the time increment specified. The optimizer will consider changing speeds only at times which are multiples of this time increment.

For the example shown in Figure 1-4, the time increment of eight hours has been chosen. Thus, in this case the optimizer will consider SOA changes with a frequency of three times a day.

The next portion of the transit plan definition process is concerned with the assessment of "fuel costs." The user is asked to specify the relative "costs" of the various SOA options with respect to one another and with

respect to other criteria considered later in the elicitation process, namely, detection aversion and evasive action costs.

The fuel costs assessed here ordinarily reflect more than just the cost of fuel associated with each SOA option. They indicate the user's aversion to using each particular SOA option relative to the others (and relative to the other two criteria) for any reason whatsoever. For example, the user may prefer an SOA of 10 knots to one of 5 knots because his ships do not respond as well to the helm in heavy seas at the slower speed.

Detection aversion, like fuel costs, must be assessed in relation to the entire set of cost criteria. Detection aversion is a measure of the cost to the user if he were detected during his planned transit (and identified as a target of interest) by hostile surveillance forces. Like fuel costs, aversion to detection could be expressed simply as a single value. It may happen, however, that a user's aversion to detection varies as a function of his progress through his transit. In particular, the user may be more concerned with detection near the end of the transit than near the beginning. To accommodate situations such as this, the user is permitted to specify a cost function over the entire course of his transit.

The final step in the transit plan definition sequence is the assessment of costs for the various evasive actions which may be employed to thwart detection.

1.2.3 Detection zone algorithm - In the current Aid, the detection zone algorithm uses hypothetical orbital parameters for five surveillance satellites. In an operational decision Aid, the ephemeris data for satellites would be supplied and updated regularly by a land-based computer network.

The output of the detection zone algorithm may be summarized in a table, as illustrated in Figure 1-5.

1.2.4 Probabilistic information - Probabilistic information is used in the dynamic program to calculate the probability that the task force will be detected when it passes through a detection zone. This information includes, for example, the probability that the weather is O.K. for detection, the probability that the satellite is operating if the weather is O.K., and the probability that the satellite will detect the task force if it is operating and the weather is O.K. The way in which these probabilities depend on the particular detection zone under consideration must be carefully specified.

For example, the probability that weather is O.K. for detection depends on when and where the detection zone occurs and on the satellite's sensors (optical sensors would be defeated by cloud cover whereas radar sensors would not). Also, the probability of detection given that the satellite is operating and the weather is O.K. depends on what local cover and deception tactics the commander can employ (COMINT sensors would be defeated if the commander employs EMCON).

A complete probability model for the Aid has been specified, but it requires probability assignments from weather and satellite experts. A practical way to make these assignments must be developed before the Aid becomes operational.

1.2.5 Decision aid output - The decision Aid supplies the commander with a recommended SOA profile and, for that profile, a listing of the satellite detection zones that will be encountered. Computer-graphic displays are shown in Figures 1-6 and 1-7.

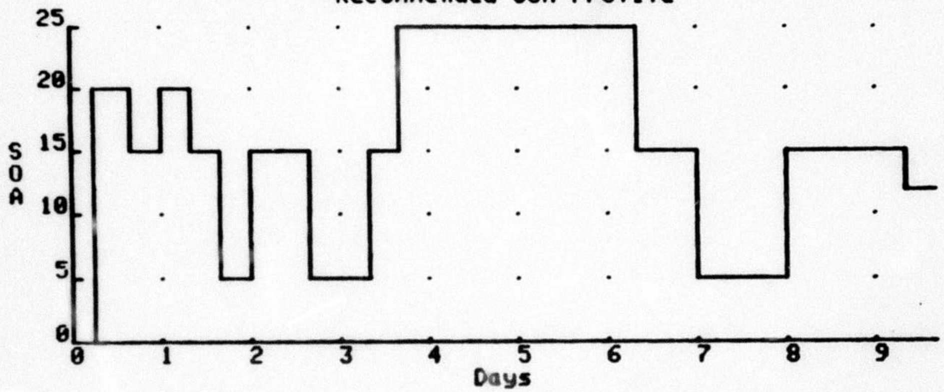
Potential Detection Zones

No	Type	Date-Time	Coverage*	No	Type	Date-Time	Coverage*
1	R	17 NOV 0633	2611-2672	31	E	18 NOV 0125	1992-2532
2	R	17 NOV 0805	1758-1828	32	C	18 NOV 0129	226- 726
3	C	17 NOV 0902	3019-3511	33	E	18 NOV 0253	960-1520
4	R	17 NOV 0935	835- 924	34	E	18 NOV 0422	0- 488
5	O	17 NOV 0952	2801-3225	35	R	18 NOV 0628	2658-2718
6	I	17 NOV 0957	2798-3128	36	R	18 NOV 0800	1805-1875
7	E	17 NOV 1006	3461-3615	37	C	18 NOV 0821	3532-3615
8	C	17 NOV 1030	1765-2317	38	R	18 NOV 0930	890- 978
9	O	17 NOV 1125	1751-2003	39	C	18 NOV 0947	2360-2929
10	I	17 NOV 1131	1759-1951	40	E	18 NOV 0955	3585-3615
11	E	17 NOV 1134	2265-2960	41	O	18 NOV 1028	2387-2633
12	C	17 NOV 1158	672-1172	42	I	18 NOV 1033	2389-2575
13	R	17 NOV 1253	3480-3542	43	C	18 NOV 1116	1180-1701
14	O	17 NOV 1258	702- 979	44	E	18 NOV 1123	2446-3097
15	I	17 NOV 1304	715- 928	45	O	18 NOV 1201	1351-1610
16	E	17 NOV 1304	1027-1658	46	I	18 NOV 1207	1362-1560
17	C	17 NOV 1325	0- 133	47	C	18 NOV 1243	142- 628
18	R	17 NOV 1424	2447-2609	48	R	18 NOV 1248	3522-3585
19	E	17 NOV 1433	0- 549	49	E	18 NOV 1253	1168-1810
20	R	17 NOV 1552	901-1004	50	O	18 NOV 1334	267- 559
21	O	17 NOV 1933	2945-3190	51	I	18 NOV 1339	280- 505
22	I	17 NOV 1939	2877-3061	52	R	18 NOV 1420	2570-2736
23	O	17 NOV 2104	1526-1852	53	E	18 NOV 1423	111- 682
24	C	17 NOV 2108	3569-3615	54	R	18 NOV 1547	964-1070
25	I	17 NOV 2109	1435-1682	55	R	18 NOV 1717	0- 42
26	O	17 NOV 2236	382- 658	56	O	18 NOV 1835	3562-3615
27	C	17 NOV 2236	2318-2803	57	I	18 NOV 1841	3493-3615
28	I	17 NOV 2241	306- 514	58	O	18 NOV 2009	2386-2759
29	E	17 NOV 2356	3185-3615	59	I	18 NOV 2014	2282-2564
30	C	18 NOV 0002	1265-1745	60	O	18 NOV 2140	1056-1359

*Nautical miles from point of departure.

Figure 1-5

POTENTIAL DETECTION ZONES

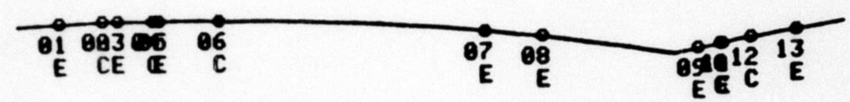


Date-Time	SOA
17 NOV 0600	20
17 NOV 1600	15
18 NOV 0000	20
18 NOV 0800	15
18 NOV 1600	5
19 NOV 0000	15
19 NOV 0800	15
19 NOV 1600	5
20 NOV 0000	5
20 NOV 0800	15
20 NOV 1600	25
21 NOV 0000	25
21 NOV 0800	25
21 NOV 1600	25
22 NOV 0000	25
22 NOV 0800	25
22 NOV 1600	25
23 NOV 0000	25
23 NOV 0800	15
23 NOV 1600	15
24 NOV 0000	5
24 NOV 0800	5
24 NOV 1600	5
25 NOV 0000	15
25 NOV 0800	15
25 NOV 1600	15
26 NOV 0000	15
26 NOV 0800	12

Figure 1-6

RECOMMENDED SOA PROFILE

Detection Zones under Recm'd SOA Profile



No	ID	Lat	Lng	Date/Time	Expos*	Action
1	E	37.3N	72.8W	17 NOV 1433	2.3	EMCON
2	C	37.6N	69.0W	18 NOV 0129	2.0	EMCON
3	E	37.6N	67.8W	18 NOV 0422	2.3	EMCON
4	C	37.8N	64.8W	18 NOV 1243	2.0	EMCON
5	E	37.8N	64.3W	18 NOV 1423	2.3	EMCON
6	C	37.8N	59.1W	19 NOV 1201	2.0	EMCON
7	E	35.0N	36.3W	22 NOV 0209	2.3	EMCON
8	E	33.8N	31.5W	22 NOV 1207	2.3	EMCON
9	E	30.9N	18.1W	24 NOV 0017	2.3	EMCON
10	C	31.8N	16.2W	24 NOV 2204	2.0	EMCON
11	E	31.9N	16.0W	25 NOV 0007	2.3	EMCON
12	C	32.9N	13.6W	25 NOV 0915	2.0	EMCON
13	E	34.5N	9.7W	25 NOV 2355	2.3	EMCON

* Minutes

Figure 1-7

DETECTION ZONES UNDER RECOMMENDED SOA PROFILE

1.3 Organization

This report is designed to serve primarily as a users' reference manual for operation of the Aid. However, in order to effectively comprehend the implications of the recommendations produced by the Aid, the user may wish to be aware of the methodology which it employs. For this reason two sections describing the most significant methodological features have been included in the report.

Section 2.0 describes the approach used to determine potential satellite detection zones for a transit, and Section 3.0 discusses the procedure used to produce the optimum SOA profile for the transit. Section 4.0 contains detailed instructions for use of the Aid.

2.0 DETECTION ZONE CALCULATION

To avoid surveillance by adversary satellites, it is obviously necessary for us to be able to calculate their locations. As a starting point, let us consider the case in which we wish to avoid surveillance by using various evasive tactics, but we do not wish to alter our planned course or our planned sequence of speeds of advance.

2.1 The Fixed Course and Fixed SOA Problem

To know when to employ our evasive actions, we must be able to compute all the intersections of the ship and the satellite for the duration of the voyage. Actually, since the satellite's sensors are able to detect ships in a circular region surrounding its current location, and this region sweeps out a swath over time, the intersections of the ship with this region or swath must be computed. We know the location of the ship as a function of time (remember that we do not wish to change course or speed from our plan), and we can easily compute the satellite's location as a function of time (it must obey the laws of motion). Thus, we can solve this problem by computing the distance between the satellite and the ship as a function of time, and then recording the time intervals when the distance is less than half the width of the swath. (The distance is simply the great circle distance between the location of a spot on the earth directly beneath the satellite, called the footprint, and the location of the ship.)

What does this function look like? There are basically two kinds of motion which contribute to the distance between the ship and the satellite. The first is a relatively rapid motion due to the satellite's revolution in its orbit, and

the second is a relatively slow motion due to the turning of the earth relative to the satellite's orbit.

For example, Figure 2-1a shows a "snapshot" of the situation at about twelve hours after departure for a particular satellite and ship: the satellite's orbit is almost on top of the ship, so that the distance between the two at about this time will be alternately very small (almost zero degrees) and then very large (almost 180 degrees) as the satellite revolves in its orbit. At about thirteen hours (Figure 2-1b) and again at about fourteen-and-a-half hours (Figure 2-1c), the orbit is still relatively close to the ship, but not as close as it was at about twelve hours. So the satellite will not get quite as close, nor quite as far away. However, at about sixteen hours (Figure 2-1d), the orbit again falls nearly on top of the ship, and the distance will again vary from near zero to near 180 degrees. Finally, at about twenty-six hours (Figure 2-1e), the earth has turned enough so that the satellite orbit is almost perpendicular to the ship, which means that the satellite remains approximately 90 degrees from the ship at all times as it revolves in its orbit. The plot of the distance between satellite and ship as a function of time for this situation is shown in Figure 2-2 for the time period between eight and thirty-two hours since departure.

2.2 Generalization to Changes in Speed of Advance

Unfortunately, this scheme does not generalize very well to more global optimization problems in which we wish to allow changes in course or speeds of advance. The reason is that until the ship's course and speed of advance have been determined, the location of the ship as a function of time is unknown. Therefore, what is needed is a procedure which will produce a three-dimensional plot of the latitudes

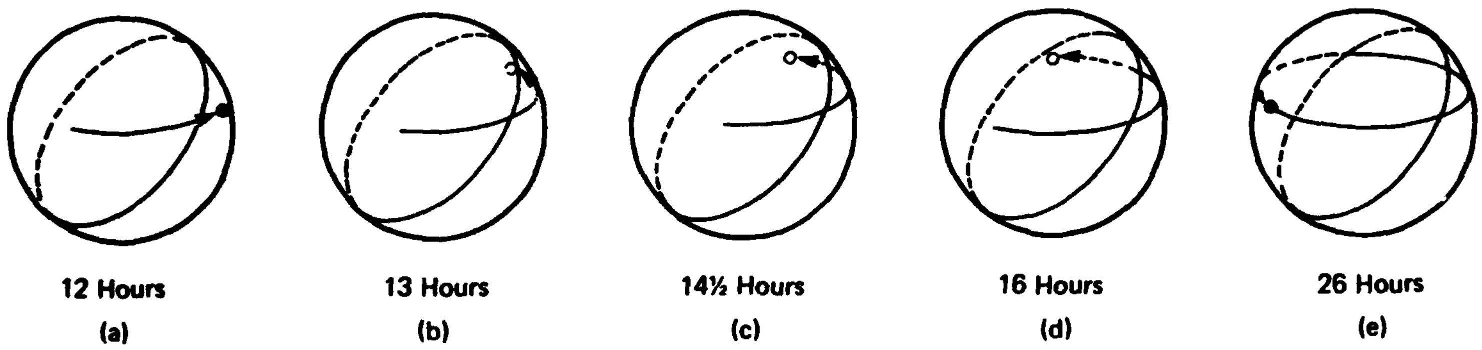


Figure 2-1

EFFECT OF EARTH'S ROTATION ON SATELLITE-SHIP DISTANCE

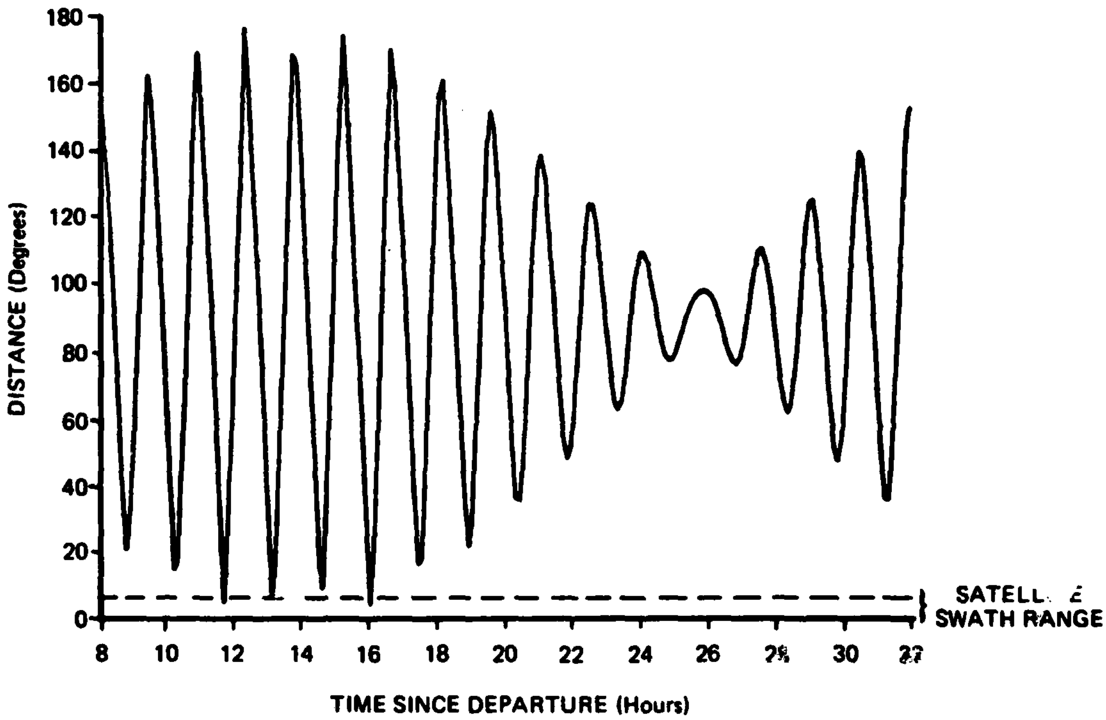


Figure 2-2

DISTANCE BETWEEN A SATELLITE AND A SHIP WITH FIXED COURSE AND SPEED

and longitudes observable by the satellite as a function of time, that is, all latitude and longitude pairs whose distance from the satellite are less than half the swath width.

Actually, a less general problem was chosen in the design of the Aid, that of minimizing detection costs along a specified track by varying only the speed of advance. A fixed track plan was chosen because a preliminary analysis showed that, due to the relative speeds of ships and satellites, varying the course of a ship had very little effect on potential intercepts, while varying the ship's speed of advance could significantly alter the probability of being detected by a satellite. This simplification has the additional advantage of reducing a three-dimensional problem (latitude, longitude, and time) to a two-dimensional problem (distance along the ship track and time). Under these conditions the detection zone procedure must determine the time intervals when the distance between the satellite footprint and the <u>ship's</u> <u>track</u> is less than half the swath width.

But each point along the ship track is analogous to a stationary ship, so that in essence the procedure outlined above would have to be solved for every point on the ship track! A different approach must be used.

The approach followed in the surveillance avoidance aid is to find all intersections of the two edges of the swath with the ship track. Then the two intersections with the edges are matched up to discover what section of the ship track, over what interval of time, is in view of the satellite sensor.

A number of practical difficulties must be overcome in the implementation of this approach. For example, the ship

track may double back on itself, creating multiple intersections with one edge but not necessarily the other (Figure 2-3). In such situations the procedure must resolve which portions of the ship track delineated by the edge intersections are within the swath, and which are outside of it. Similarly, near the start or finish of a ship track there are often intersections with only one of the edges (Figure 2-4). Here the procedure must be careful not to match this edge intersection with another edge intersection.

How do satellite intersections appear on a graph of time versus distance? Let us take as an example a west-to-east transit from Norfolk, Virginia, to Gibraltar, and an intersection by a satellite travelling in a northeast direction with a sensing range of 300 nautical miles (Figure 2-5). The sensing area is considered to be a circle surrounding the satellite, and the intersection begins when the circle just touches the ship track at some time, t_1 (Figure 2-6). Then at some later time, t_2, the swath reaches its maximum extent in a westward direction (Figure 2-7). At another time, t_3, the swath has reached as far east as possible along the track (Figure 2-8); and finally, at t_4 the swath again just touches the ship track as the intersection is completed (Figure 2-9). When the distances along the ship track which are covered by the swath are plotted as a function of time, the result is an asymmetric oval on the time-distance graph (Figure 2-10). However, the difference between t_1 and t_4 for this particular intersection is 1.4 minutes, whereas the difference between the minimum and maximum distance is 740 nautical miles. When this oval is scaled to fit on a time-versus-distance chart for a typical transit of, say, 10 days over 3500 nautical miles, it appears as a vertical straight line (Figure 2-11). (The importance of the time-versus-distance chart will be explained in Section 3.0.)

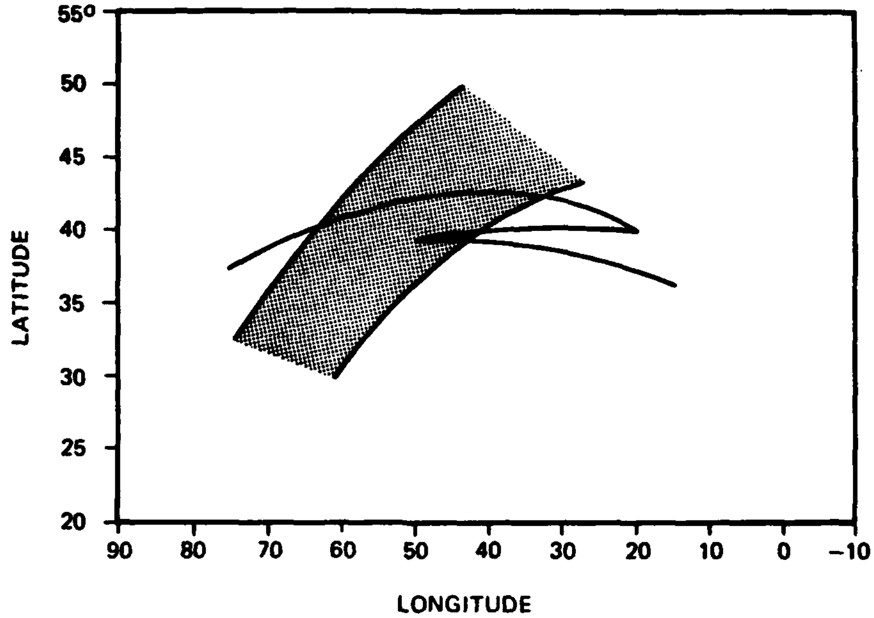


Figure 2-3

MULTIPLE INTERSECTIONS OF AN
EDGE OF THE SWATH WITH THE SHIP TRACK

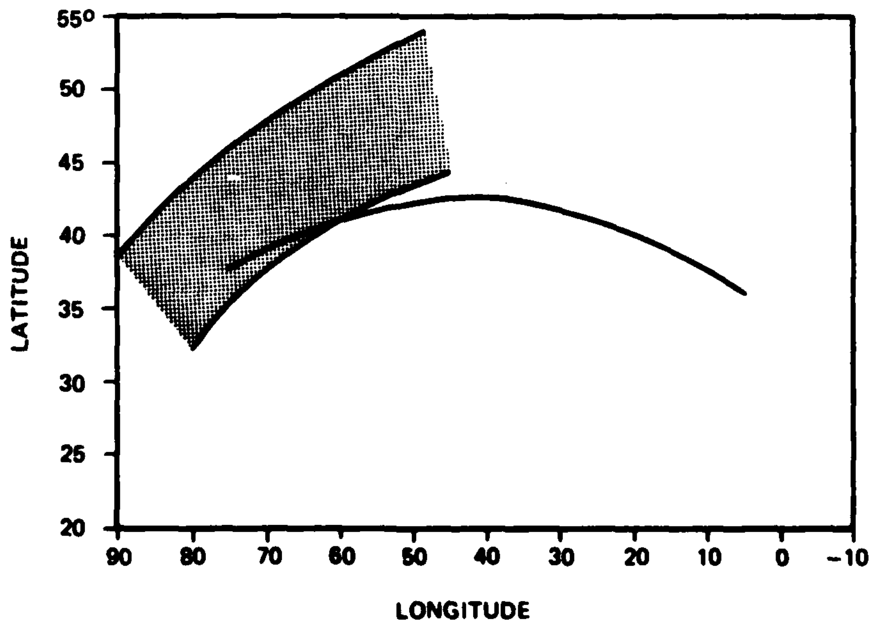


Figure 2-4

INTERSECTION OF ONLY ONE EDGE
OF THE SWATH WITH THE SHIP TRACK

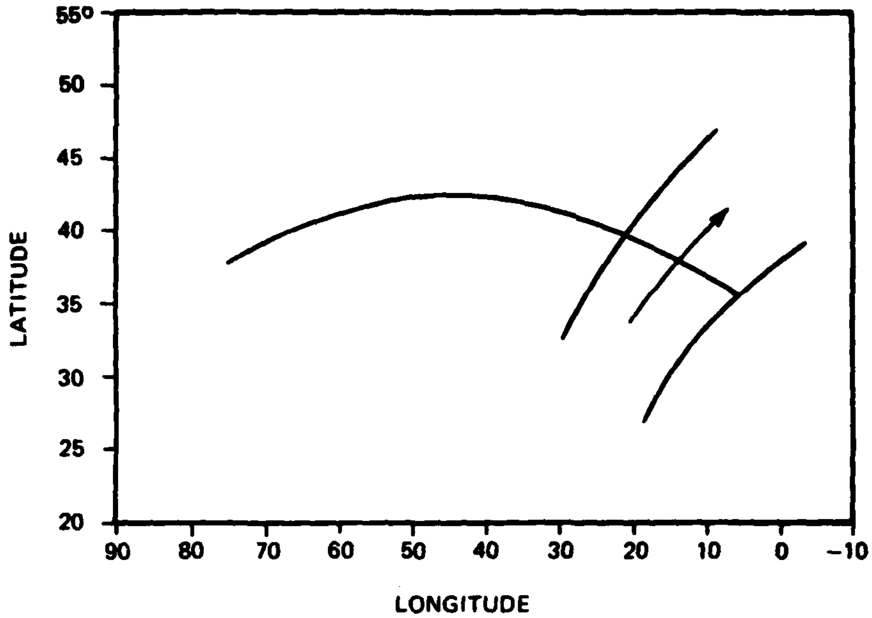


Figure 2-5

HYPOTHETICAL PATH OF SATELLITE FOOTPRINT OVER SHIP TRACK

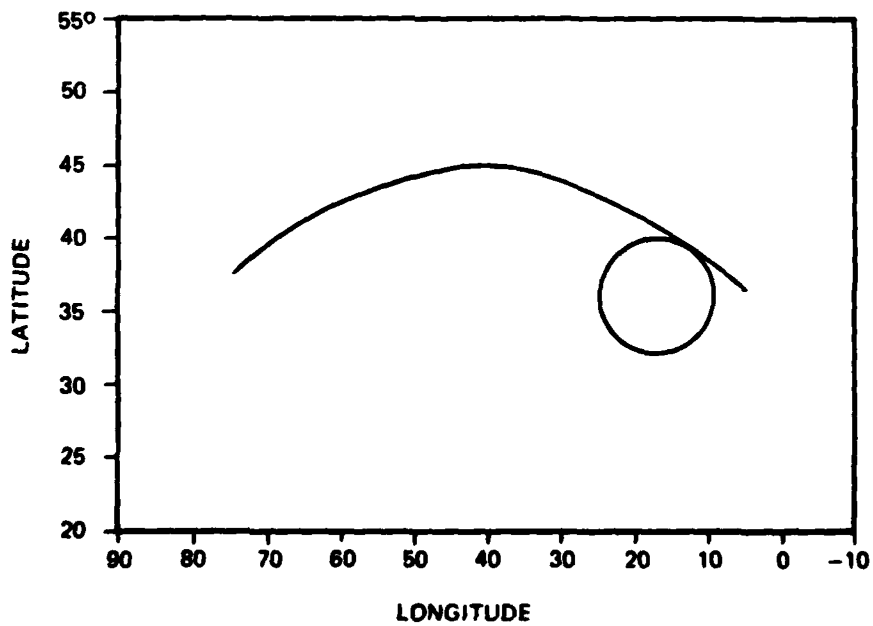


Figure 2-6

FIRST POINT AT WHICH SATELLITE'S FIELD OF VIEW INCLUDES SHIP TRACK AT TIME t_i

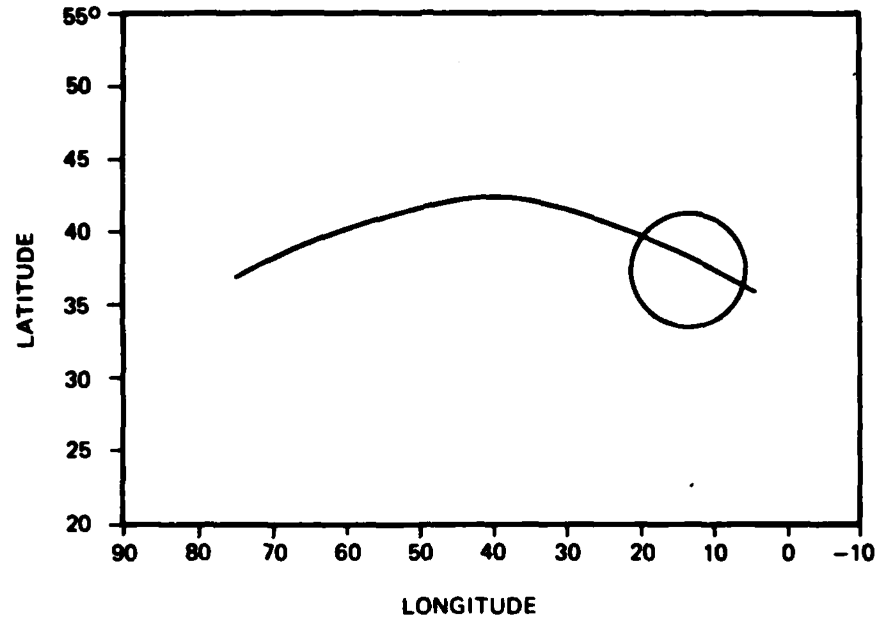


Figure 2-7

POINT AT WHICH SATELLITE'S FIELD OF VIEW INCLUDES THE MAXIMUM WESTERN PORTION OF THE SHIP TRACK ON THIS PASS, t_2

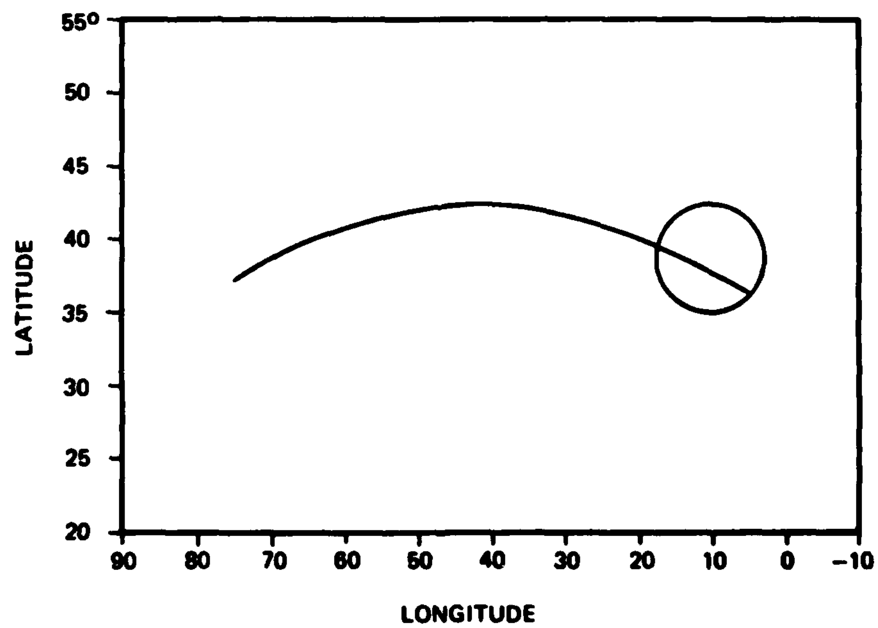


Figure 2-8

POINT AT WHICH SATELLITE'S FIELD OF VIEW INCLUDES THE MAXIMUM EASTERN PORTION OF SHIP TRACK ON THIS PASS, t_3

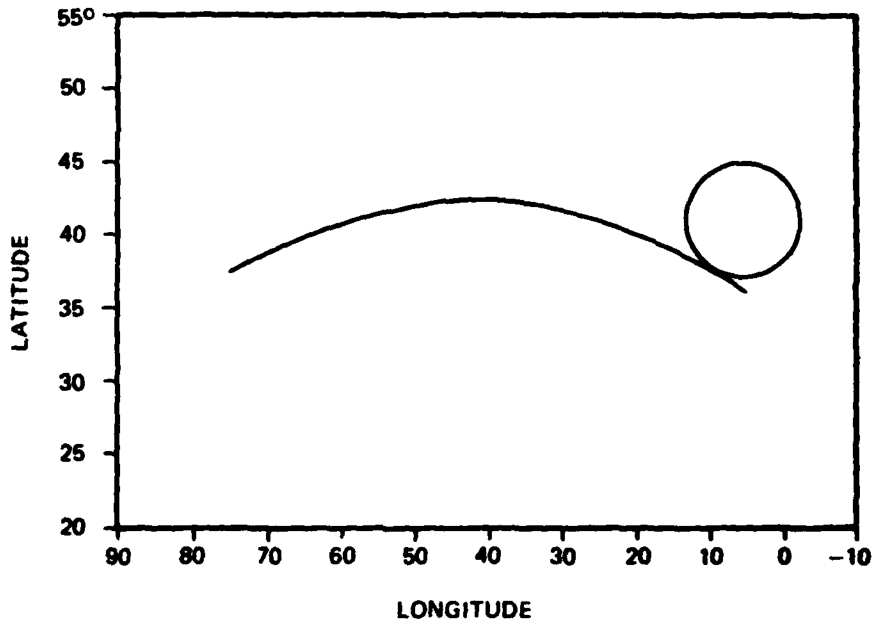


Figure 2-9

LAST POINT AT WHICH SATELLITE'S FIELD OF VIEW INCLUDES SHIP TRACK, t_4

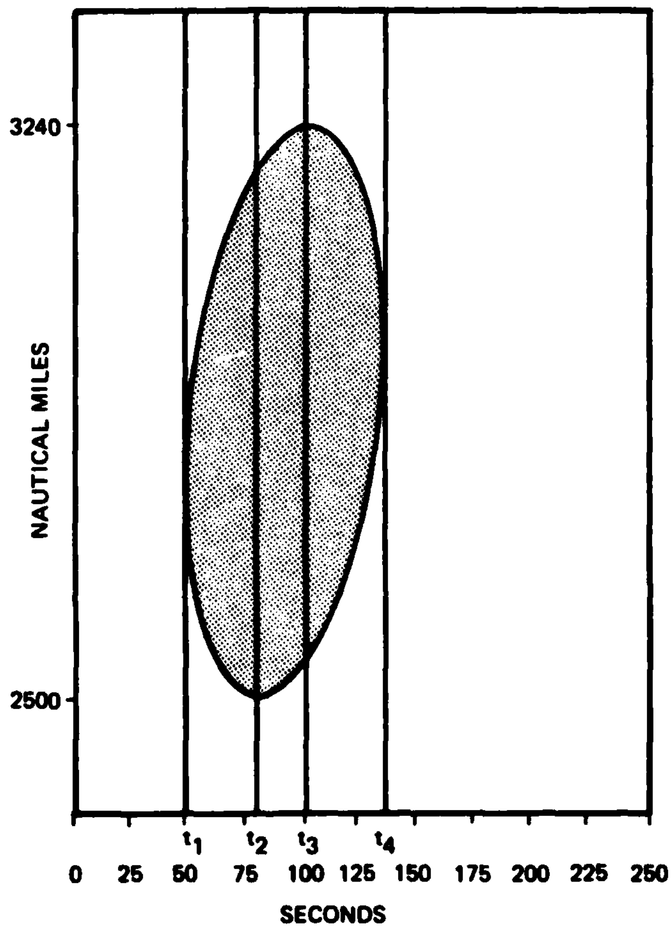


Figure 2-10

SET OF DISTANCES ALONG SHIP TRACK WHICH
ARE VISIBLE TO THE SATELLITE AS A FUNCTION OF TIME

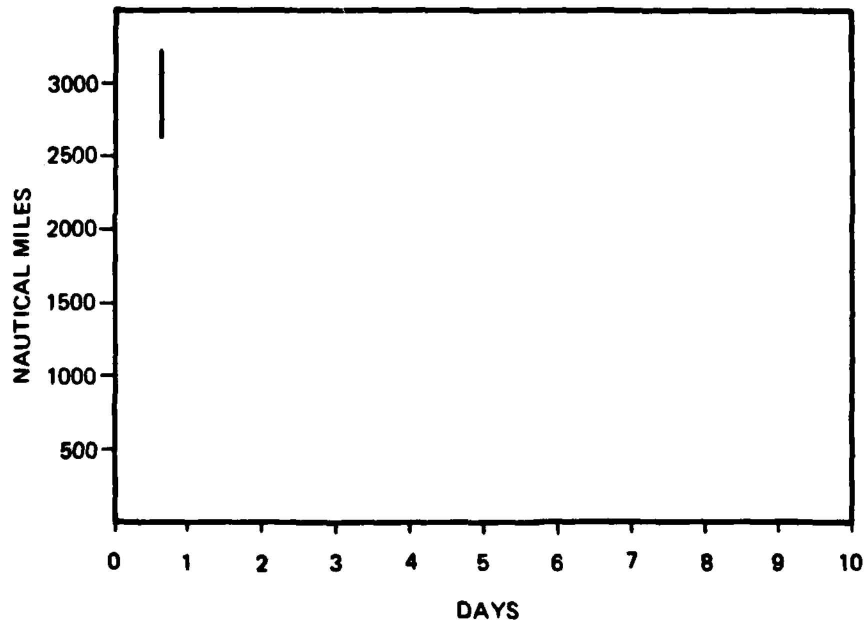


Figure 2-11

FIRST INTERSECTION PLOTTED ON SHIP'S TIME-DISTANCE CHART

On the next pass, the earth has turned approximately 22.5 degrees, so the satellite swath intersects the ship track at a location which is farther west (Figure 2-12). This produces a second vertical line on the time-versus-distance chart one satellite period later, covering a section of the ship track which is farther west, and therefore closer to the departure point in this case (Figure 2-13). Similarly, subsequent passes produce swaths farther west (Figures 2-14 through 2-17) until the earth has turned enough so that the swath is off the end of the ship track. The next intersections occur when the downward part of the satellite orbit begins to intersect the eastern part of the ship track (Figures 2-18 and 2-19). This also progresses westward as the earth turns (Figures 2-20 through 2-25). At this point, for this satellite and ship track, there will be a period of time during which the part of the satellite orbit that is in the northern hemisphere moves around the back side of the earth. Finally, the upward part of the orbit will begin to intersect the east end of the ship track, and the cycle starts again.

It is important to note that, although the width of the swath is 600 nautical miles from side to side in this example, many of the intersections on the time-versus-distance chart over much larger portions of the ship track. For example, the intersection shown in Figure 2-18 extends from 3,240 miles from departure to 1,725 nautical miles from departure. This range of 1,515 nautical miles occurs because in this intersection the satellite orbit and the ship track are more parallel to one another. It would be possible for a satellite with a smaller inclination to cover the ship track for several thousand miles if it happened to line up with the ship track.

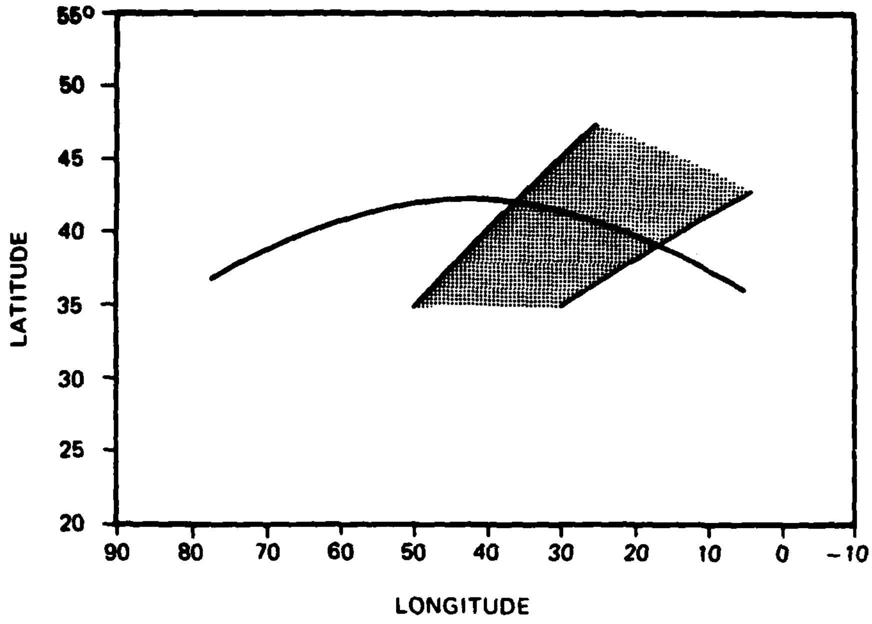


Figure 2-12
PATH OF SATELLITE'S FOOTPRINT ON SECOND PASS

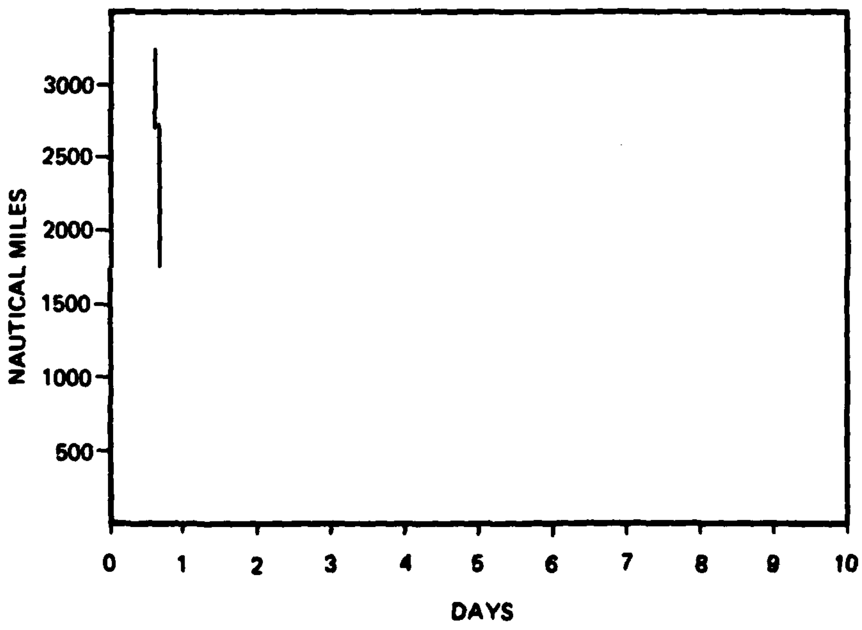


Figure 2-13
FIRST TWO SATELLITE INTERSECTIONS

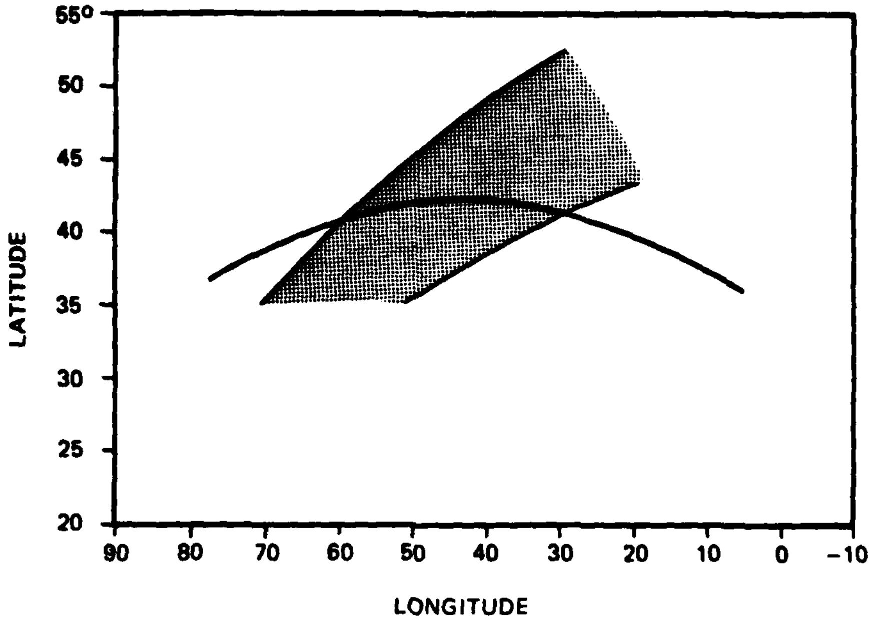


Figure 2-14
SATELLITE SWATH ON THIRD PASS

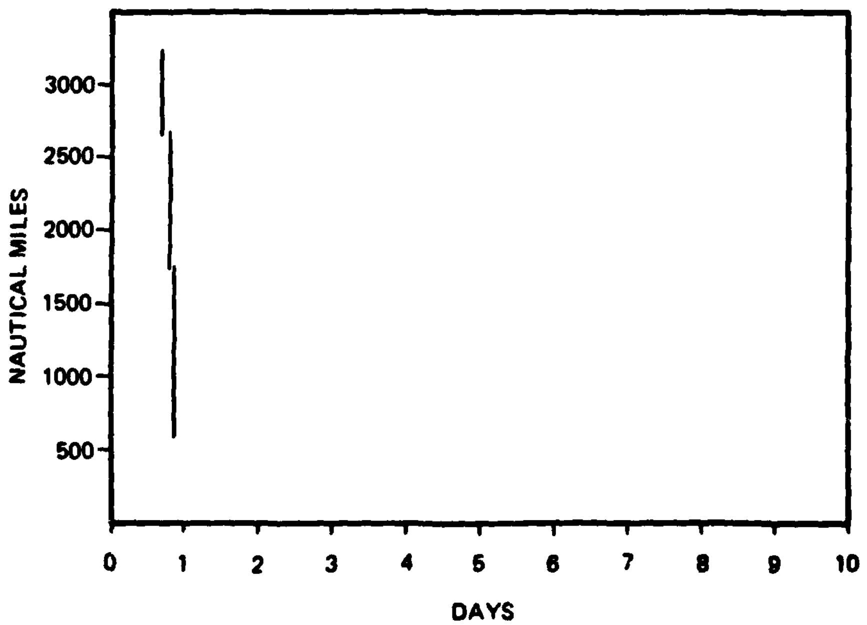


Figure 2-15
FIRST THREE SATELLITE INTERSECTIONS

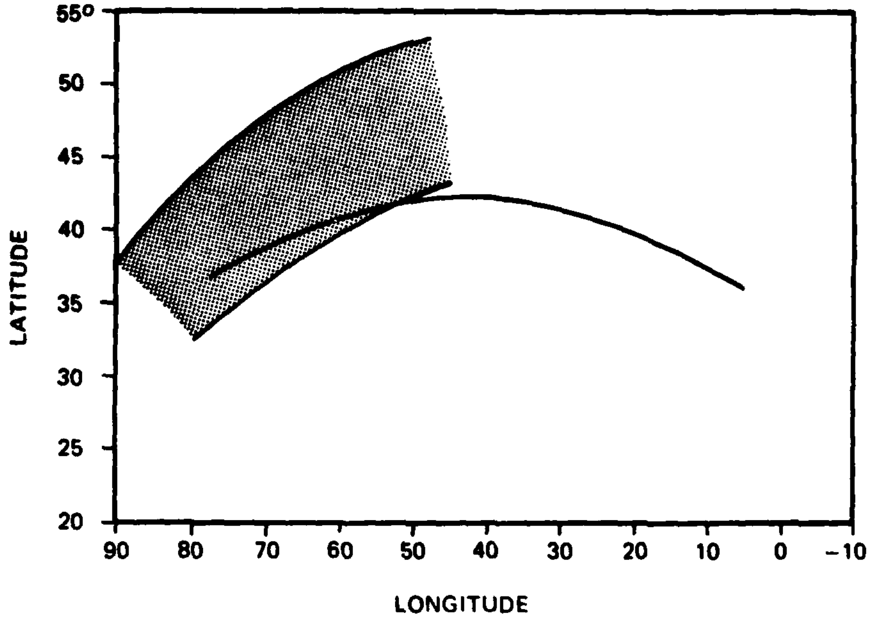


Figure 2-16
SATELLITE SWATH ON FOURTH PASS

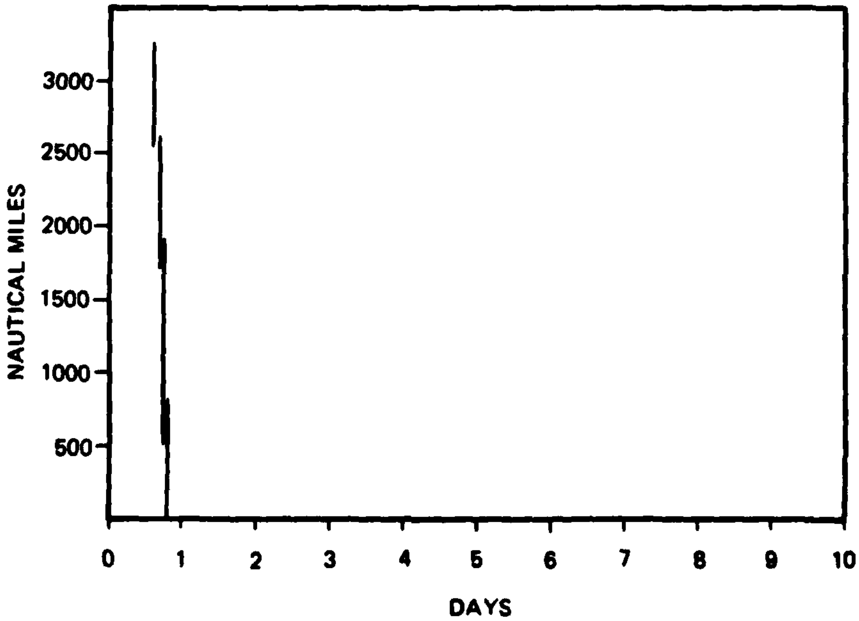


Figure 2-17
FIRST FOUR SATELLITE INTERSECTIONS

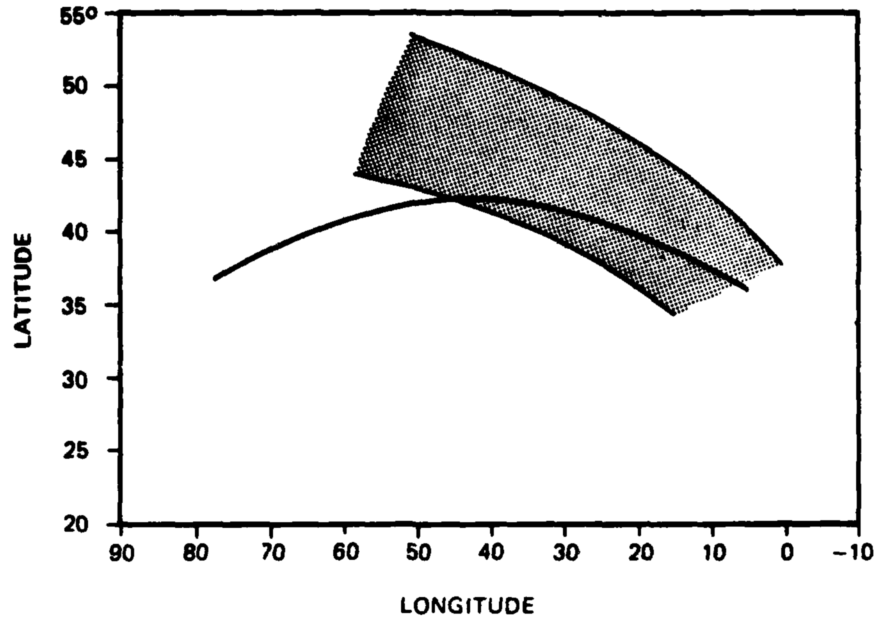


Figure 2-18
SATELLITE SWATH ON FIFTH PASS

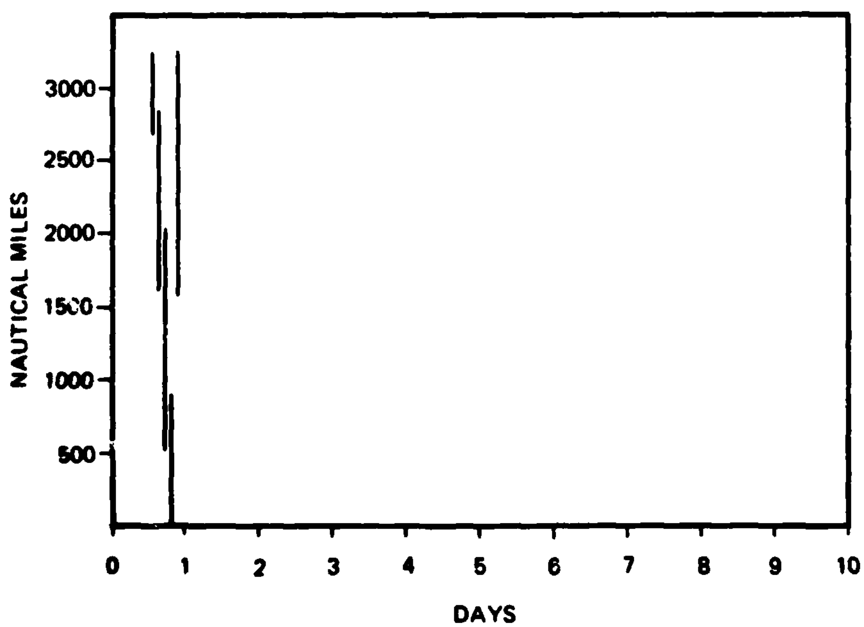


Figure 2-19
FIRST FIVE SATELLITE INTERSECTIONS

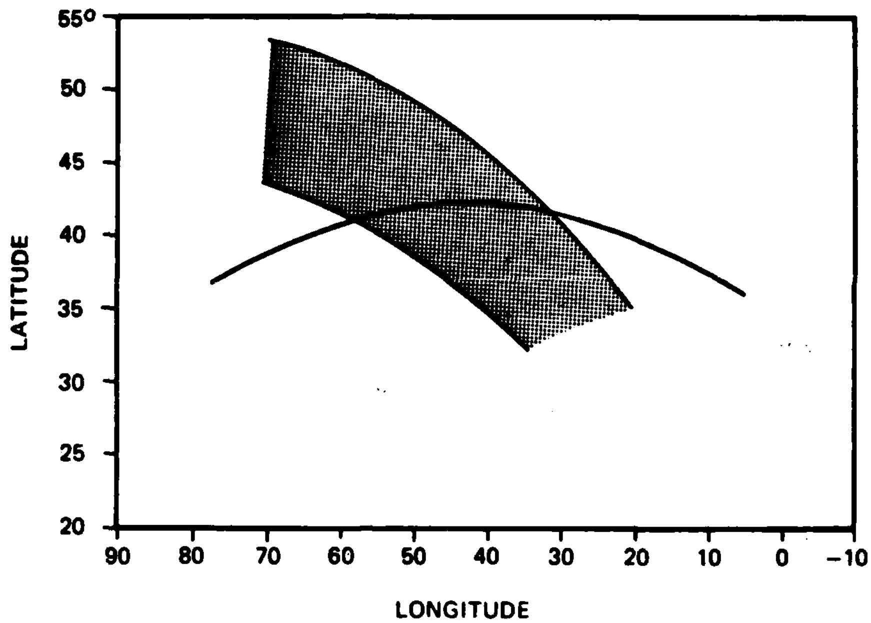


Figure 2-20

SATELLITE SWATH ON SIXTH PASS

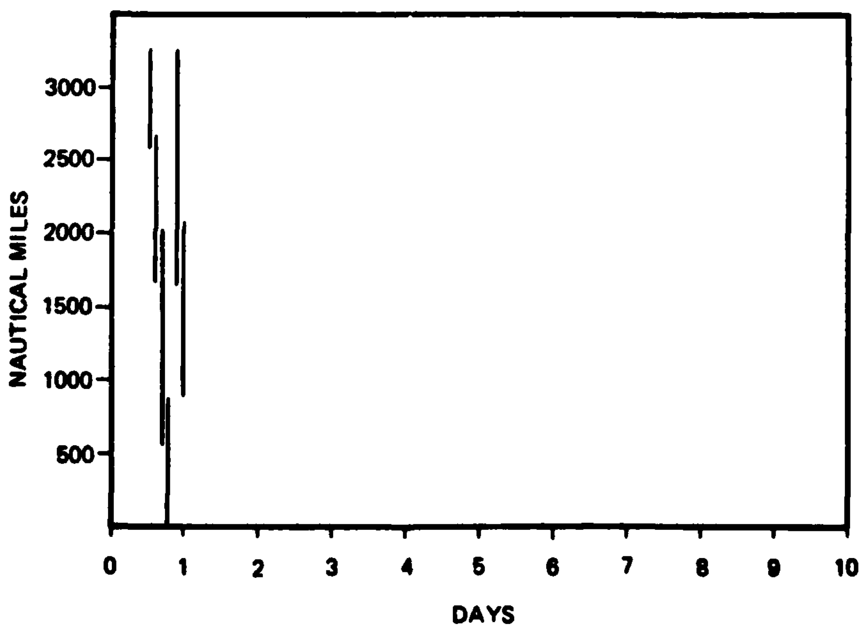


Figure 2-21

FIRST SIX SATELLITE INTERSECTIONS

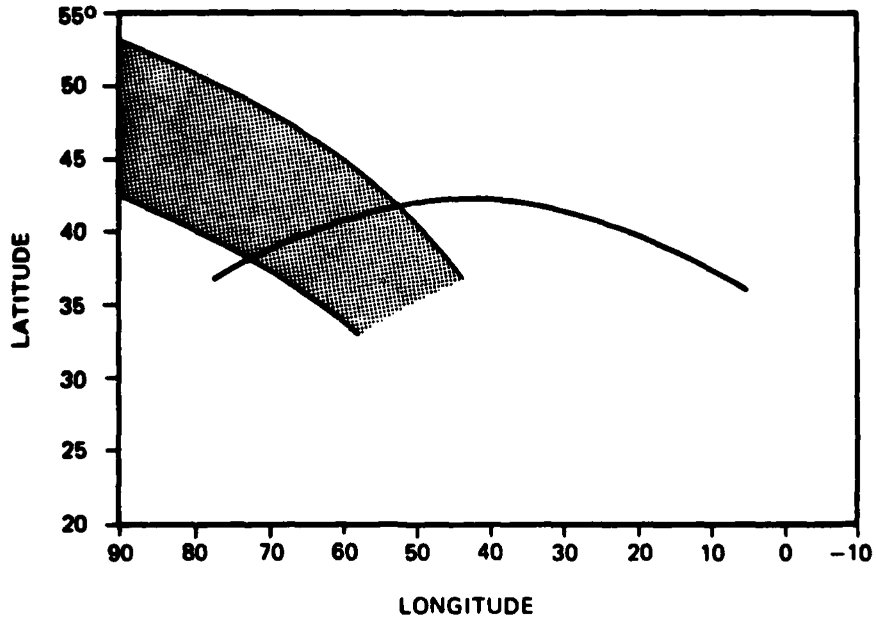


Figure 2-22
SATELLITE SWATH ON SEVENTH PASS

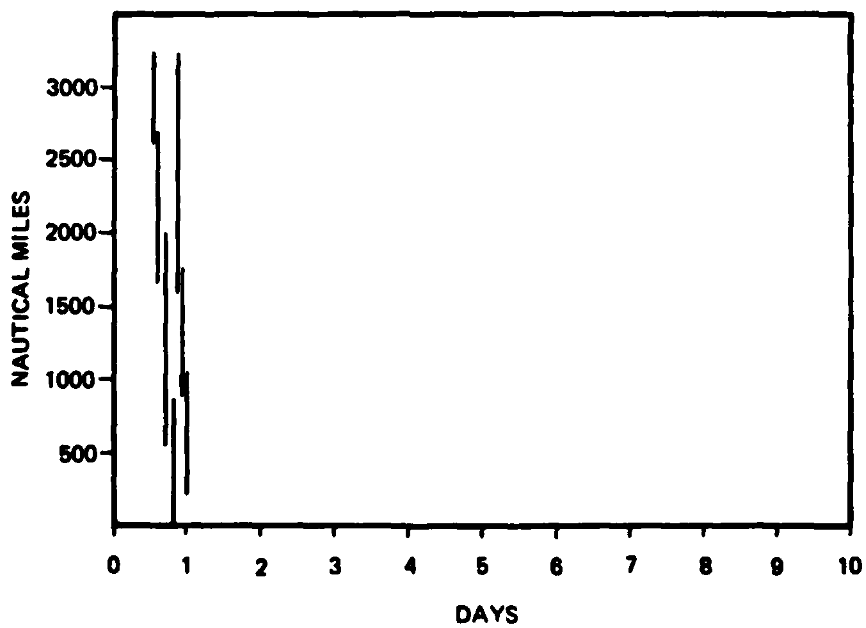


Figure 2-23
FIRST SEVEN SATELLITE INTERSECTIONS

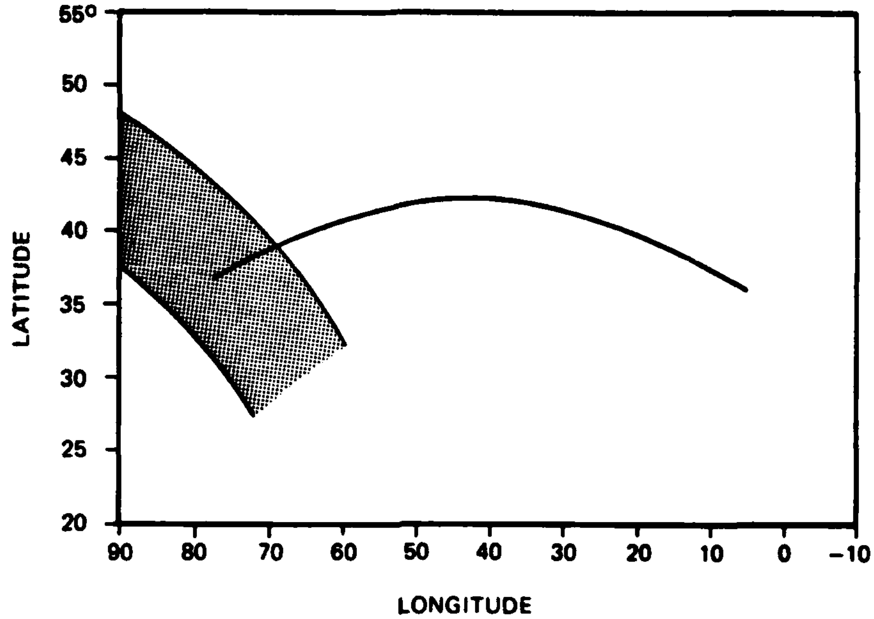


Figure 2-24
SATELLITE SWATH ON EIGHTH PASS

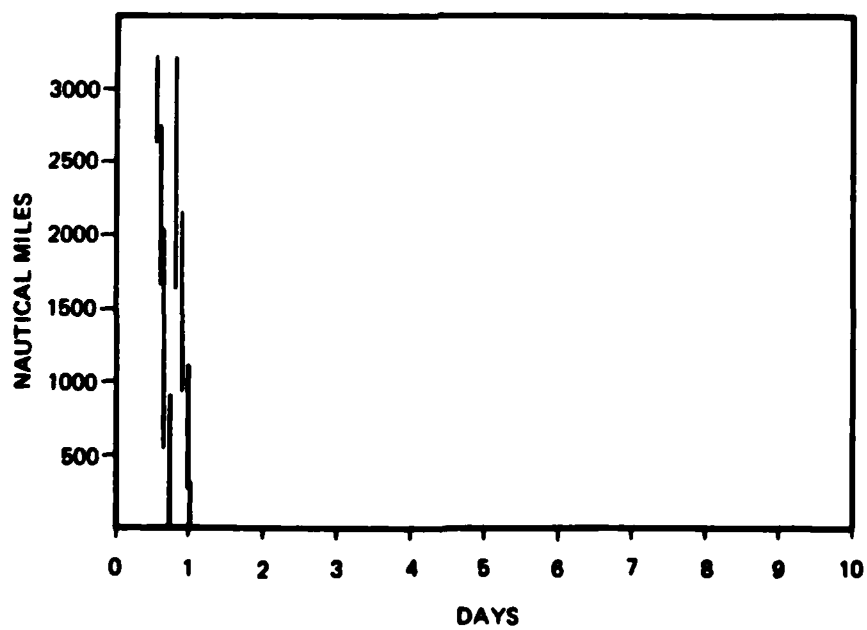


Figure 2-25
FIRST EIGHT SATELLITE INTERSECTIONS

3.0 OPTIMIZATION PROCEDURE

The purpose of the optimization procedure is to arrive at the best transit plan between the departure point and the destination point along a specified track minimizing the expected cost of detection by potential satellite surveillance by varying the ship's speed of advance.

3.1 The Optimization Problem

The problem space is most easily shown by using a graph in which the distance from the departure point along the ship track is the y-axis, and the time since departure is the x-axis (Figure 3-1). This is the time-versus-distance chart introduced in Section 2.0. Since the ship track and the departure and arrival times have been specified by the user, a rectangle can be drawn on the graph which contains all possible distances from the departure point and all possible times between departure and arrival. Any possible transit will be represented by a curve which joins the lower left corner of the rectangle to the upper right corner, and the speed of advance at any point in time will be given by the slope of the curve at that point.

There are further restrictions, however. The ship has a maximum speed of advance, and this further constrains the set of permissible points. That is, there are many locations in the rectangle which cannot be reached from the departure point, or from which the destination cannot be reached without exceeding the maximum speed of advance (Figure 3-2).

Similarly, the minimum speed of advance may exclude other regions: points which cannot be reached unless the ship travels at a speed of advance which is less than the

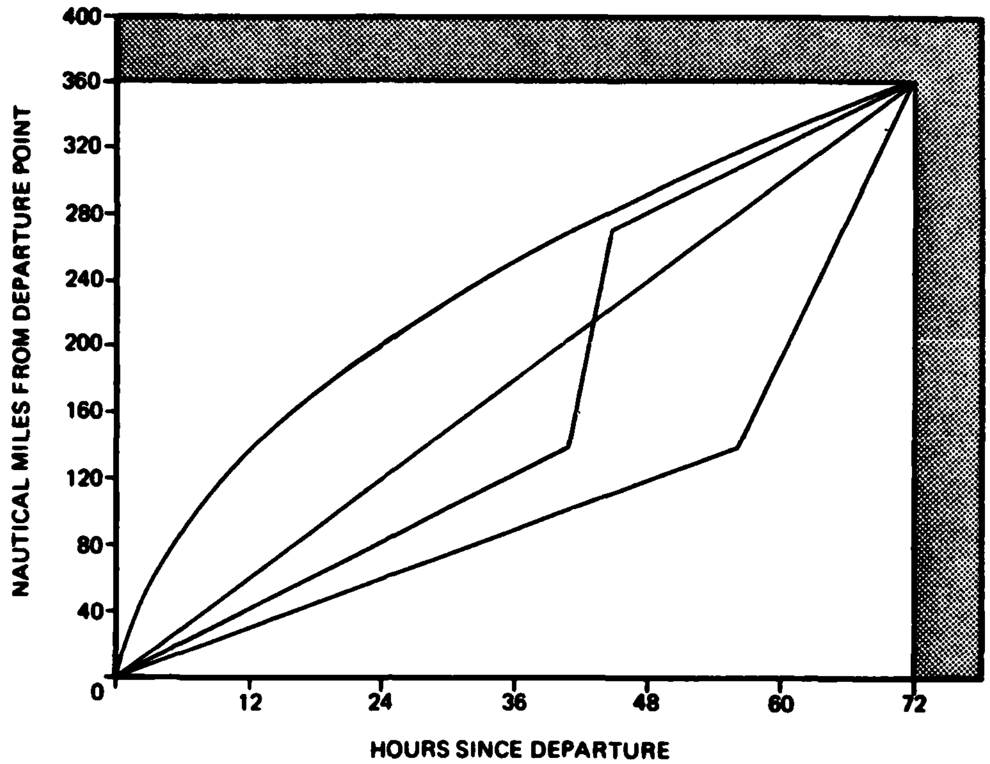


Figure 3-1

HYPOTHETICAL SHIP TRANSIT CURVES

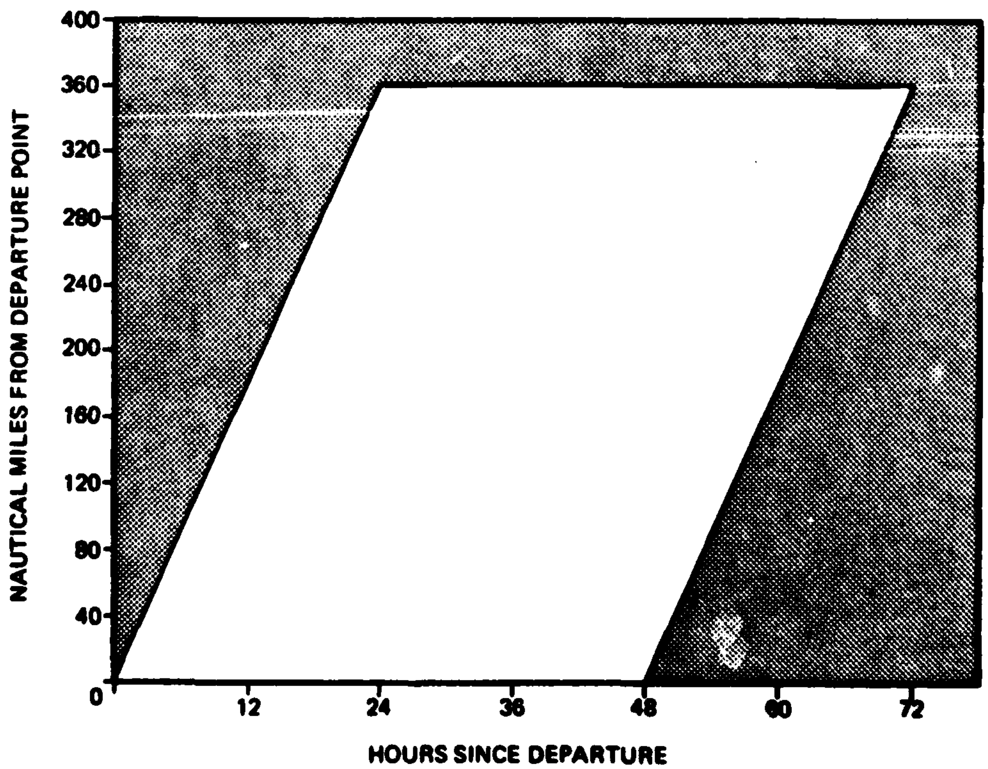


Figure 3-2

CONSTRAINTS ON MAXIMUM SPEED OF ADVANCE

minimum (Figure 3-3). The minimum lines together with the maximum lines form a parallelogram of permissible distance-time points which the ship might occupy (Figure 3-4). (Note that the minimum and maximum SOA constraints must be observed within the parallelogram, as well.)

There is no requirement that the minimum speed of advance be positive. It may be positive, if the task force commander wishes to maintain a continuing advance toward his destination; it may be zero, indicating that the commander will allow periods of circling or otherwise maintaining his position for some periods of time. The speed of advance may be negative, indicating that movement in a direction towards the departure point is permitted. In the case of a zero or negative minimum speed of advance, two of the edges of the parallelogram coincide with the edges of the rectangle (Figure 3-5). This means that the ship may actually leave later than the scheduled departure time and/or may arrive earlier than the scheduled arrival time.

Superimposing the satellite detection zones described in Section 2.0 upon the parallelogram chart, as shown in Figure 3-6, results in a graphical representation of the surveillance avoidance problem. The objective is to find a "path" through the maze of potential detection zones which minimizes the expected cost of detection. The "path" must lie totally within the parallelogram and its slope at any point must satisfy the constraints imposed for minimum and maximum SOA.

If all detection zones are assumed to have equal importance, the optimum intercept avoidance path, or profile, is one which minimizes the number of detection zones encountered during a transit. For the example of Figure 3-6, which depicts the situation for a single satellite, the best profile can probably be determined by visual examination of the chart.

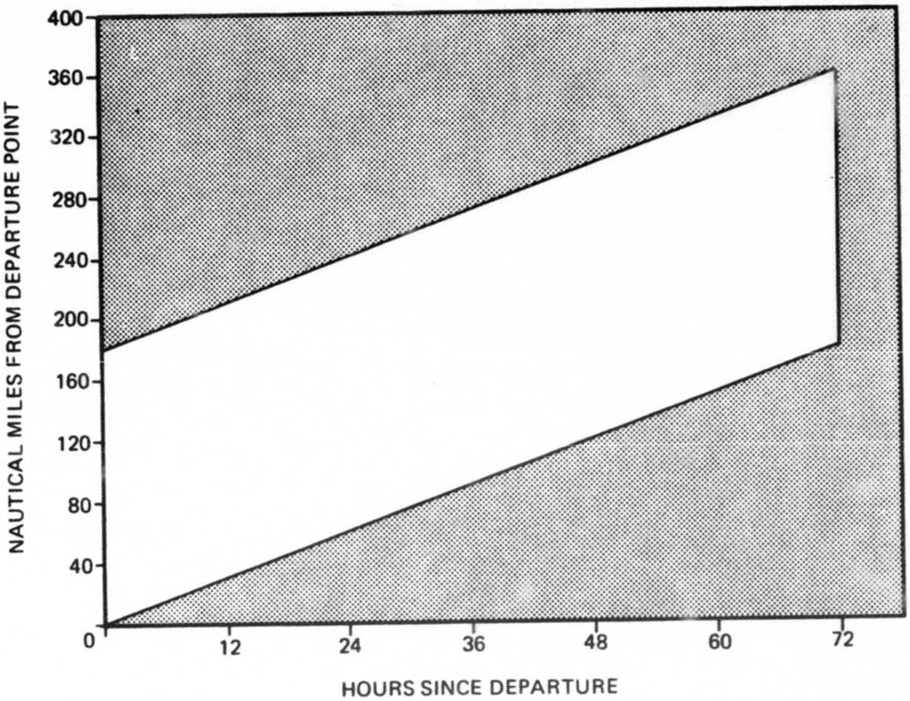


Figure 3-3
CONSTRAINTS ON MINIMUM SPEED OF ADVANCE

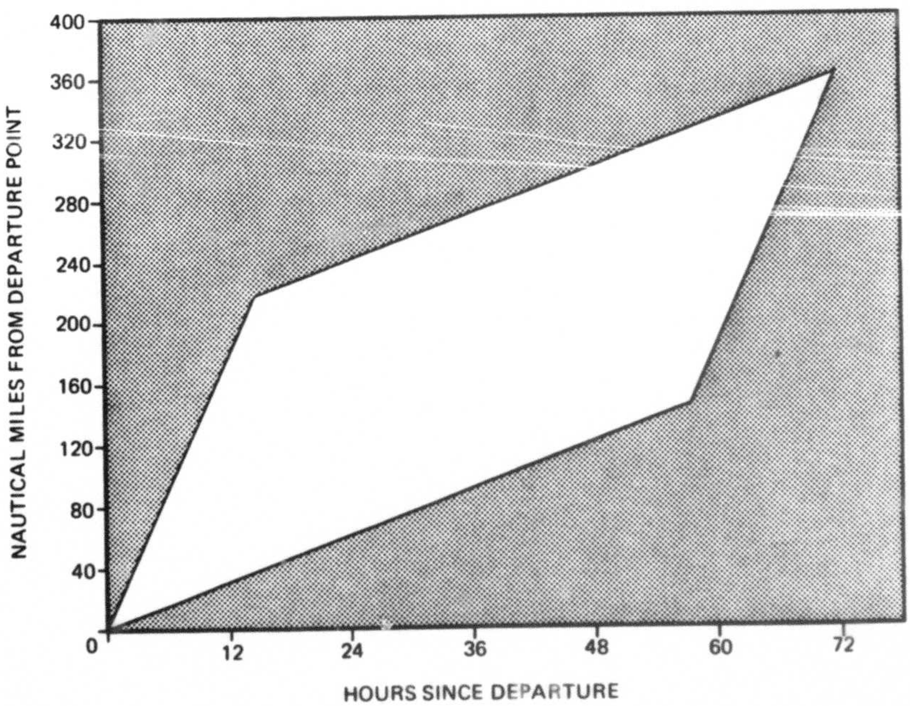


Figure 3-4
SET OF POSSIBLE TIME-DISTANCE POINTS

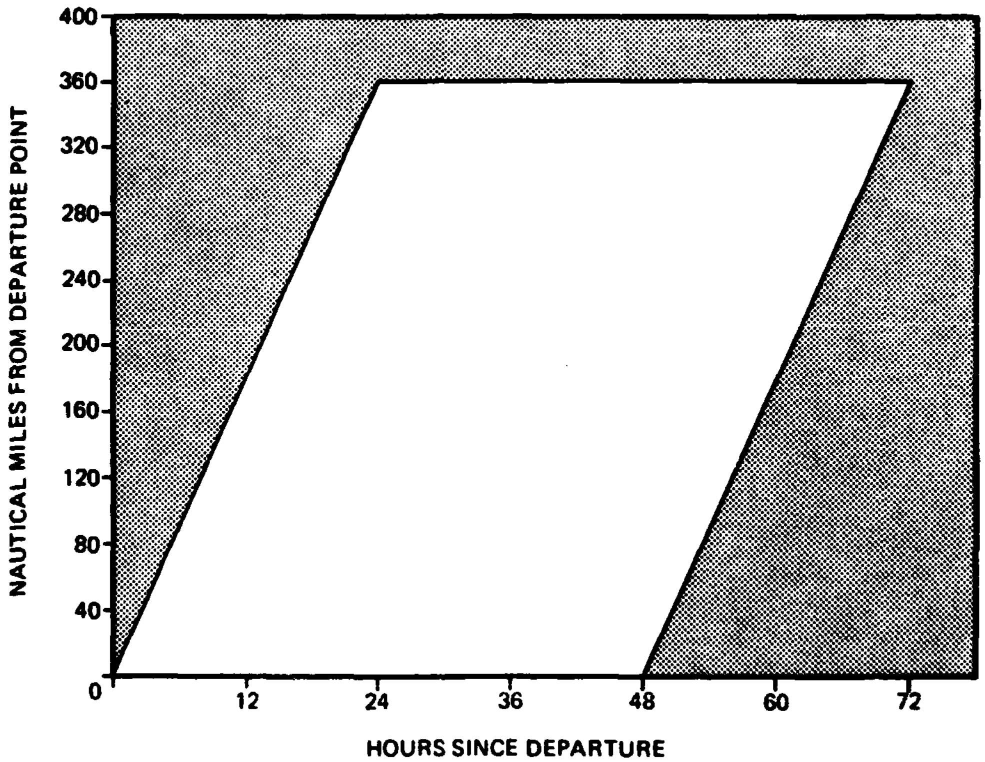


Figure 3-5

SET OF POSSIBLE TIME-DISTANCE POINTS WHEN MINIMUM SPEED OF ADVANCE IS ZERO OR NEGATIVE

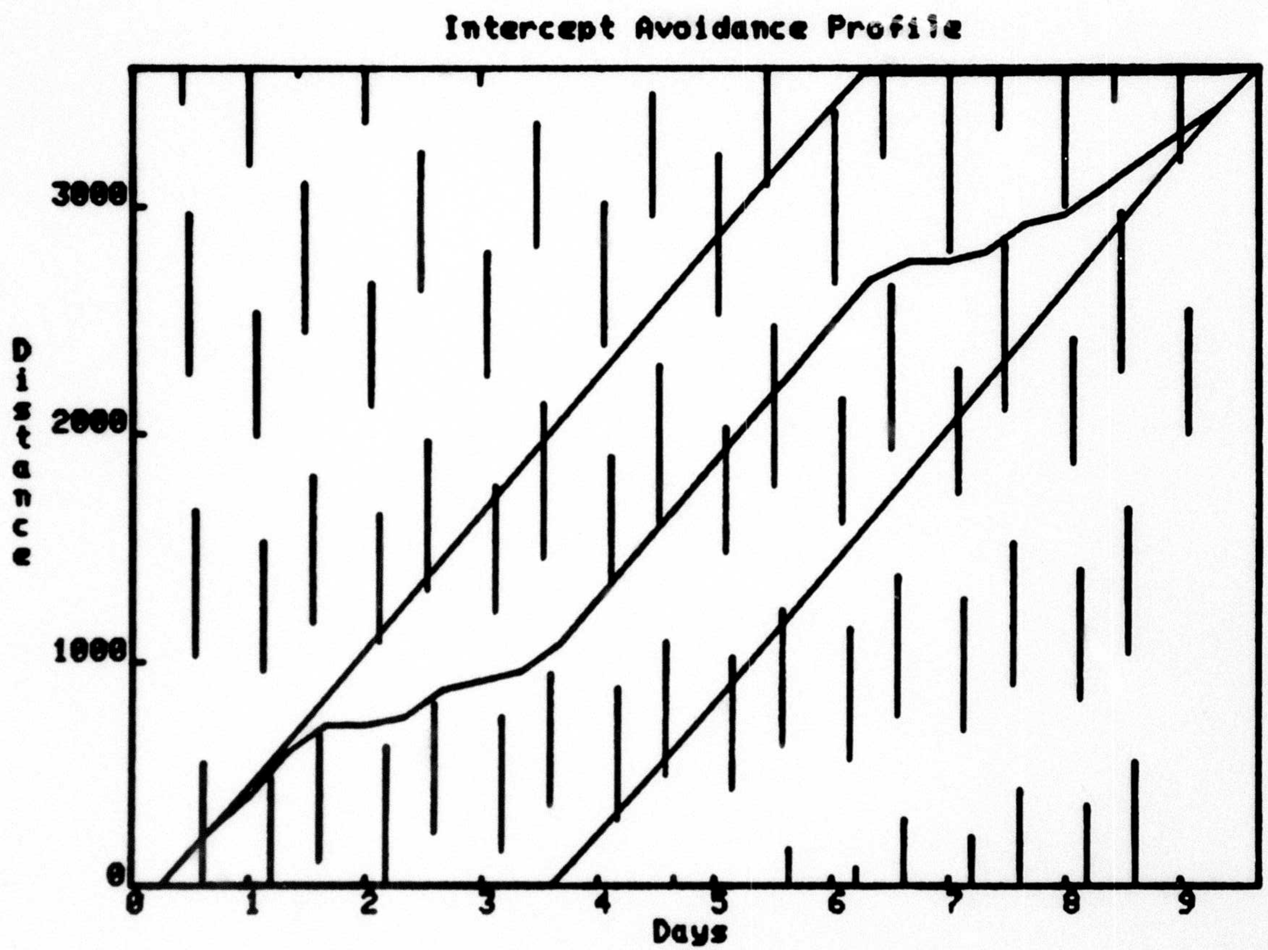


Figure 3-6

SATELLITE DETECTION ZONES ON A TIME-VERSUS-DISTANCE CHART WITH AN SOA CONSTRAINT PARALLELOGRAM

If there are several surveillance satellites, however, the task of avoiding detection zones becomes more complex (Figure 3-7).

Passing through a detection zone does not necessarily mean that the task force will be detected. If cloudy weather is forecast for the first few days of the transit, for example, the probability of detection by an optical satellite during that period will probably be very small. At the same time, the sensing capabilities of a radar satellite generally are not affected by cloud cover. Accordingly, it may be preferable to pass through two or more optical detection zones rather than a single radar detection zone. Therefore, the probability of detection within a detection zone, which is not represented in Figure 3-7, may be an important consideration in choosing a speed profile.

The cost of a detection may also be important. Are early detections more costly than later ones? Is the first detection more costly than subsequent detections? In addition, all speeds of advance are not equally costly. It may be preferable to risk a detection which has a low probability rather than maintain the maximum speed of advance for an extended period of time.

If models for the probability of a detection, the cost of a detection within each detection zone, and costs of speeds of advance are available, then we can select the SOA profile that minimizes the expected cost of the transit.

Finally, it may be possible to lower the probability of being detected by a given satellite through the use of various evasive actions such as EMCON, electronic countermeasures, etc. Both the efficacy and costs of these measures should be considered.

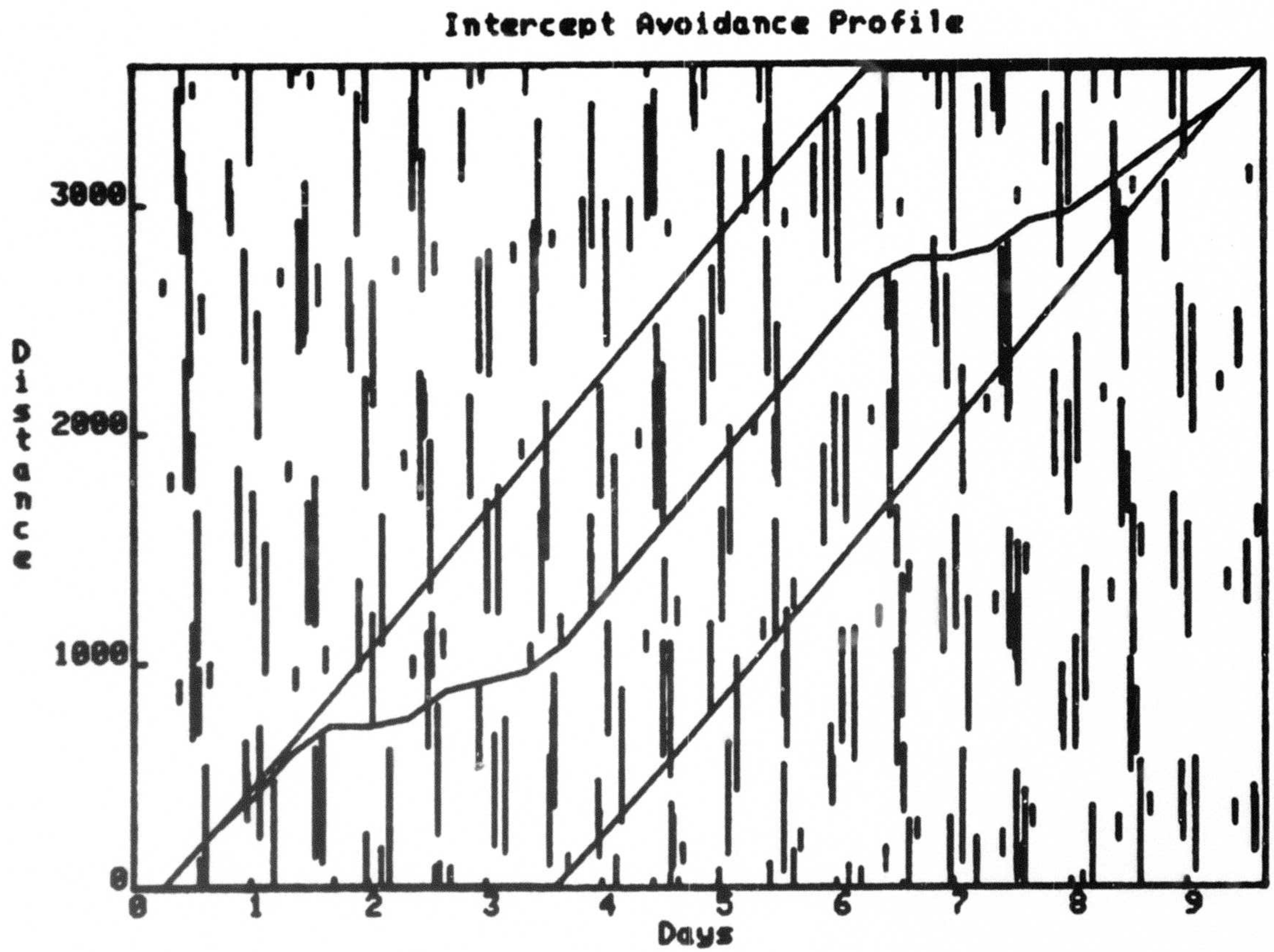


Figure 3-7

A TIME-VERSUS-DISTANCE CHART
WITH DETECTION ZONES FOR SEVERAL SATELLITES

These factors all conspire to render visual examination of the time-versus-distance chart an ineffective technique for minimizing the expected cost of detection. Fortunately, the problem can be solved by using well known decision analysis and optimization techniques. The optimization approach which has been adopted is described in the remainder of this section.

3.2 The Optimization Approach

The method of optimization on which the global optimizer is based is dynamic programming. This methodology has the following characteristics: 1) time is divided into a number of discrete stages, i.e. points at which decisions may be made; 2) there are a number of discrete states which the system may occupy at a particular stage; and 3) all the information needed to make decisions at any stage is contained in the state description and does not depend on the particular path of preceding states, decisions, and events which led to that state. In everyday terms, this means that the best way to get to where you are going has nothing to do with how you got to where you are now.

Now let us apply the idea of dynamic programming to the satellite avoidance problem. The first step is to divide the total time of the transit into stages. Stages are defined as points at which decisions can be made from among the available options. In the satellite avoidance problem, since the options are the alternative speeds of advance, the stages are conveniently determined by the time intervals specified by the user between opportunities to change the speed of advance.

The next step is to define the states. If we imagine ourselves at some stage in the middle of the transit, the question is, what information do we need in order to decide intelligently what to do? In other words, what information must be included in the state description?

First of all, we need to know how far we are from the departure point along the ship track. This distance tells us where we are on the earth, and the stage we are in tells us the day and time. Thus, we have enough information to determine which potential satellite interceptions might be encountered.

The second kind of information required is the current probability that the ship is already being tracked. This variable accounts for and represents the history of prior detections, and it is necessary because the probability and cost of detection ordinarily depend on the probability that the adversary knows the ship is there. If a large number of previous detections have occurred and it is almost certain the ship is being tracked, then the ship will undoubtedly be noticed by satellites overhead unless evasive action is taken. On the other hand, it is probably not worthwhile expending a great deal of effort to avoid being detected if the adversary already knows the location of the ship.

Thus, the two kinds of information which should be in the state description are the distance of the ship from the departure point along the ship track, and the probability that the ship is already being tracked. In order to use dynamic programming, these factors must be treated as discrete values. In the global optimizer, the probability of being tracked is divided into twenty-one states, 0.00 0.05 0.10 ... 0.95 and 1.0. The distance of the ship from the departure point is already divided by the stages and the speed of advance options: if there are opportunities to change the speed of advance every t hours, and the permissible

speeds of advance differ by v knots, then the possible distance states will differ by vt nautical miles.

Dividing the total trip distance into discrete distance states and the total time of the trip into stages creates a lattice of distance-time points within the parallelogram (Figure 3-8). However, the total time is unlikely to be exactly divisible by the time increment, nor is the total trip likely to be traversable by using only the specified speed of advance options. To put it another way, the departure point and the destination are unlikely to fall on lattice points on the graph.

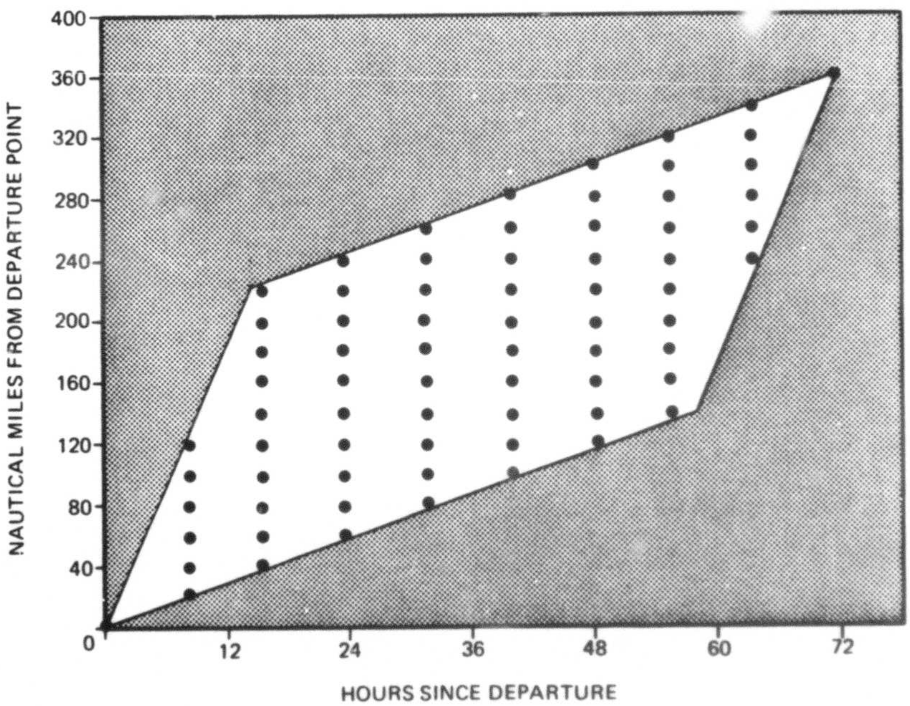


Figure 3-8
LATTICE COMPOSED OF STAGES AND DISTANCE STATES

Any solution to this problem is bound to be somewhat arbitrary. The solution adopted in the global optimizer is the following: 1) all stages except the first and last occur at even multiples of the standard time increment, starting at midnight of the day preceding departure; and 2) the first and last time intervals fall somewhere between one and two times the standard time increment. The former condition causes the stages to occur at natural hours of the day. The latter condition ensures that the speed of advance options which result from the odd time intervals after the first and next-to-last stages are not less than the minimum speed of advance nor greater than the maximum speed of advance.

3.3 The Dynamic Programming Algorithm

One can think of the global optimizer as a substitute decision maker. Its job is to examine many possible decision situations and to make decisions the way we would if we had the time and the energy to examine each of those situations. In the dynamic programming formulation, the decision situations are defined by the set of stages and states, so we must determine how we would like the substitute decision maker to make decisions using this information.

The available options at a particular stage and in a particular state consist of a set of possible speeds of advance. The current state indicates our distance from the departure point (and therefore indicates our location), so we can determine all possible satellite interceptions we might encounter using each speed of advance (Figure 3-9). However, in order to decide among them, the expected cost for each of these speeds of advance must be computed. This is simply the cost of travelling at that particular speed of advance plus the sum of the expected costs for each of the possible interceptions which would occur using that speed of

advance, assuming that we used the most cost-effective evasive action for each interception.

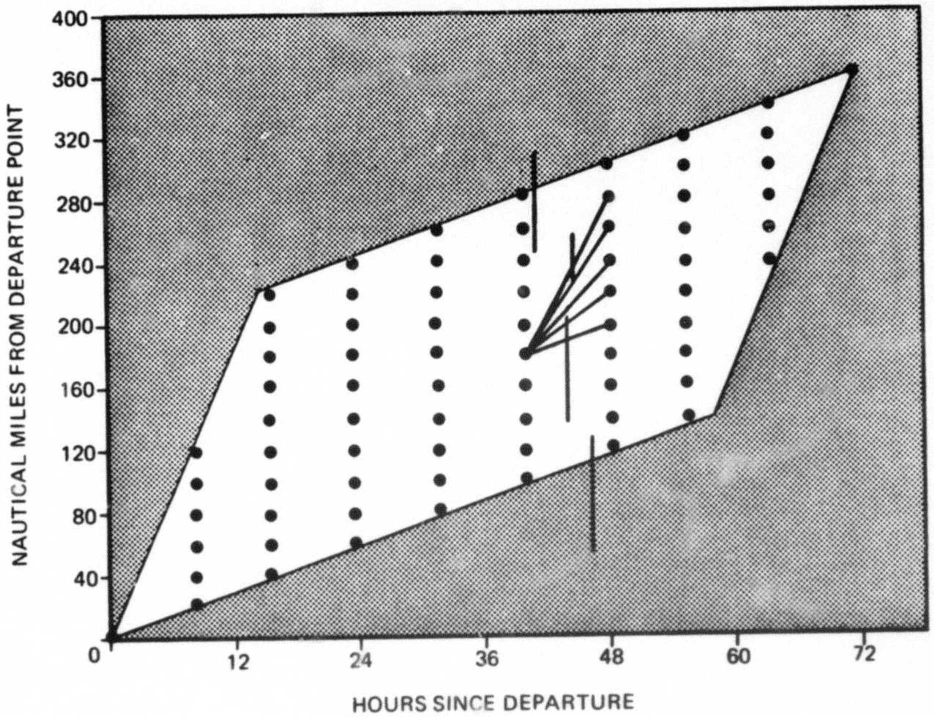


Figure 3-9

POSSIBLE SATELLITE INTERCEPTIONS ENCOUNTERED FROM A LATTICE POINT USING EACH POSSIBLE SOA

Unfortunately, this presents a nasty problem: Choosing the speed of advance option with the lowest expected cost over the next time interval might result in a very costly situation later on. That is, the best action at any point in time depends not only on the costs incurred during the next time interval, but also on the costs incurred during future time intervals. Thus we cannot really decide which speed of advance to choose without knowing what the future costs might be.

But there is one stage in which this is not a problem. In the next-to-the-last stage, the only costs we need to

consider are the costs incurred in the final time interval, because after that we will have reached our destination, and there will be no further future costs.

Of course, until we get there we do not know which state we will occupy in the next-to-the-last stage, so suppose we examine every state in the next-to-the-last stage, and for each one we compute the costs for each speed of advance option and choose the one with the smallest cost. Then for future reference we record both the action chosen for each state and its cost.

Now let's look at the second-to-the-last stage. We could not make a rational decision before because the future costs of our actions were unknown. But we have just noted the costs associated with the best choice of speeds for each possible state in the next-to-the-last stage, which are precisely the future costs we need in the second-to-the-last stage. So we proceed as before: consider in turn each state in the second-to-the-last stage, and for each state compute the cost of each speed of advance option (fuel costs plus expected costs of detection) in the current time interval. However, before choosing among them, we determine which state in the next-to-the-last stage each speed of advance option would take us to, and add the future cost previously recorded for that state to the cost of the current speed of advance option. This yields the total cost of choosing that particular speed of advance option in the current stage and choosing the best speed in all future stages. Naturally, we choose the option which has the lowest total cost. Proceeding as we did before, we evaluate each state in the second-to-the-last stage ($stage_{n-2}$), and record the best action and its cost for future reference.

But now we have all the information needed to make rational decisions at each state in $stage_{n-3}$. Obviously, we

can continue with this procedure by processing successively earlier and earlier stages until we reach the first stage, at the time of departure, at which point we are done.

3.4 Evaluating Potential Interceptions

In the preceding section, we assumed that we could calculate the expected cost of detection for every potential interception, and further, that this cost resulted from our use of the most cost-effective evasive action. How are these costs calculated?

For any given speed of advance option at a particular state in a given stage, we can determine the time and location of all potential interceptions. Each potential interception represents a decision problem (Figure 3-10). For each possible evasive action, there are two possibilities (Figure 3-11): either the adversary has been tracking the ship, or he has not. In either case the satellite detects the ship or it does not, although the probabilities and costs of detection will generally differ in the two cases. Thus, the expected cost for taking evasive action_i in this situation is equal to the sum of the cost of the action itself and the expected cost of detection.

If the adversary is tracking the ship, the expected cost is simply the product of the probability of detection, given tracking, and the cost of detection given tracking. Similarly, if the adversary is not tracking the ship, the expected cost is the probability of detection, given not tracking, times the cost of detection given not tracking. Since we do not know whether the adversary is tracking the ship or not, the expected cost of detection for evasive action_i is a weighted average of the two expected costs (weighted by the probability of their occurrence).

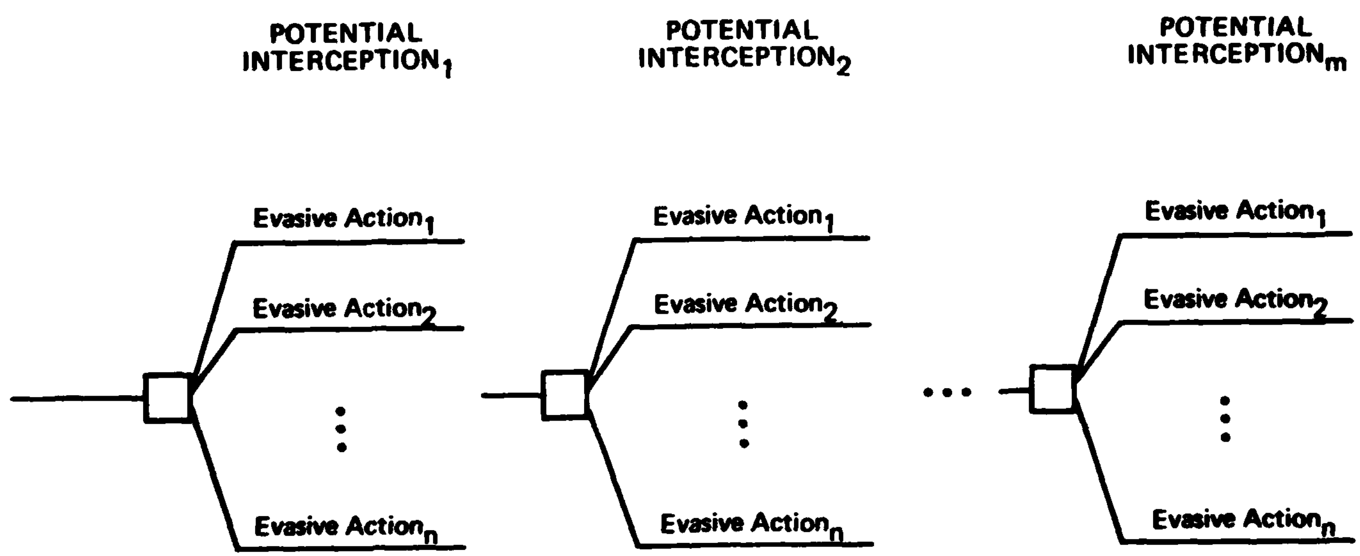


Figure 3-10

DECISION TREE FOR TAKING EVASIVE ACTIONS

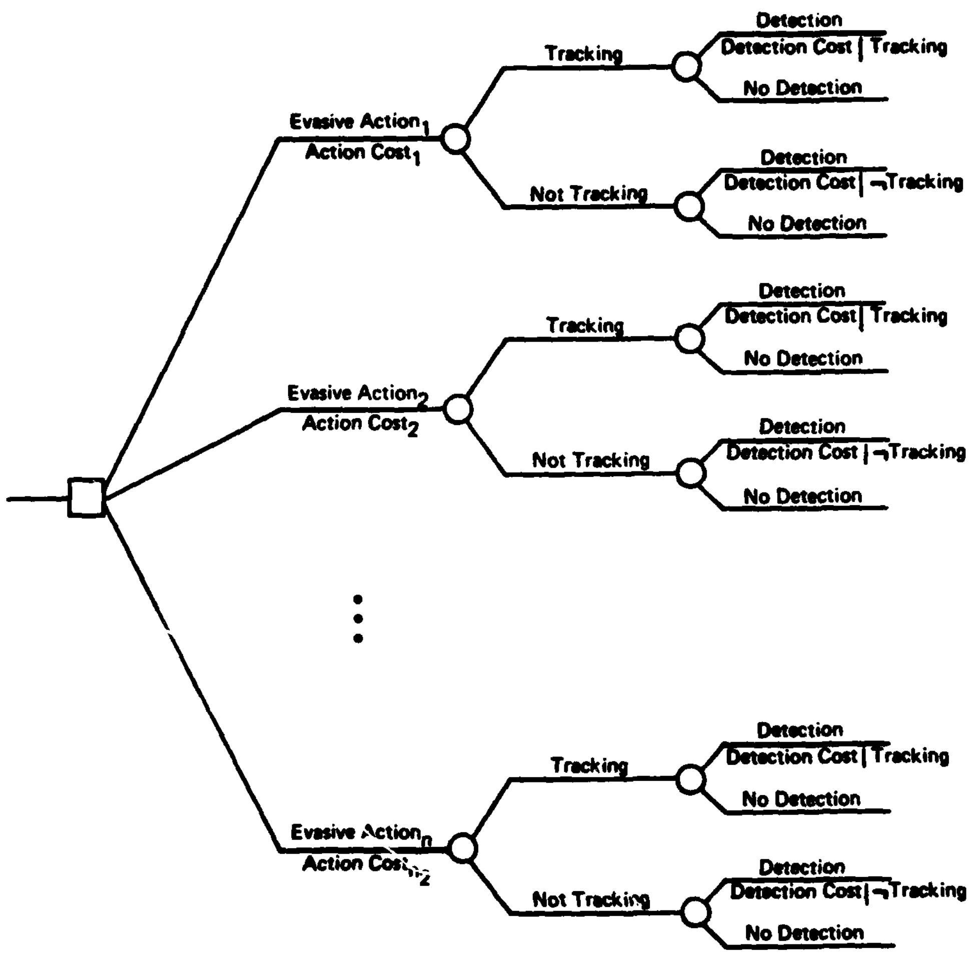


Figure 3-11

EVASIVE ACTION DECISION TREE
INCLUDING POSSIBILITIES OF TRACKING AND DETECTION

To facilitate the assessment of the detection probabilities, two additional conditioning factors are used (Figure 3-12). Thus, the probability of detection given tracking is equal to the product of the following three factors: the probability that the weather is O.K. for this satellite type, the probability that the satellite sensor is operating given that the weather is O.K. for detection, and the probability that the satellite will detect the ship given that the adversary is tracking, the sensor is operating, and the weather is O.K. for detection. Exactly the same kind of computation is used for the probability of detection given that the adversary is not tracking the ship.

3.5 Optimization Results

The end result of the optimization process is a recommended best speed of advance for each stage of the transit. On the time-versus-distance chart the recommended SOA profile will appear as shown in Figure 3-13. Another representation of this result is a stage-by-stage plot of SOA versus time (Figure 3-14).

In addition to the recommended SOA profile, the optimizer determines the best evasive action to employ for each detection zone through which the SOA profile passes (Figure 3-15).

A computer software package which implements the optimization procedure discussed in this section and which produces the results shown in Figures 3-13, 3-14, and 3-15 is described in detail in Section 4.0.

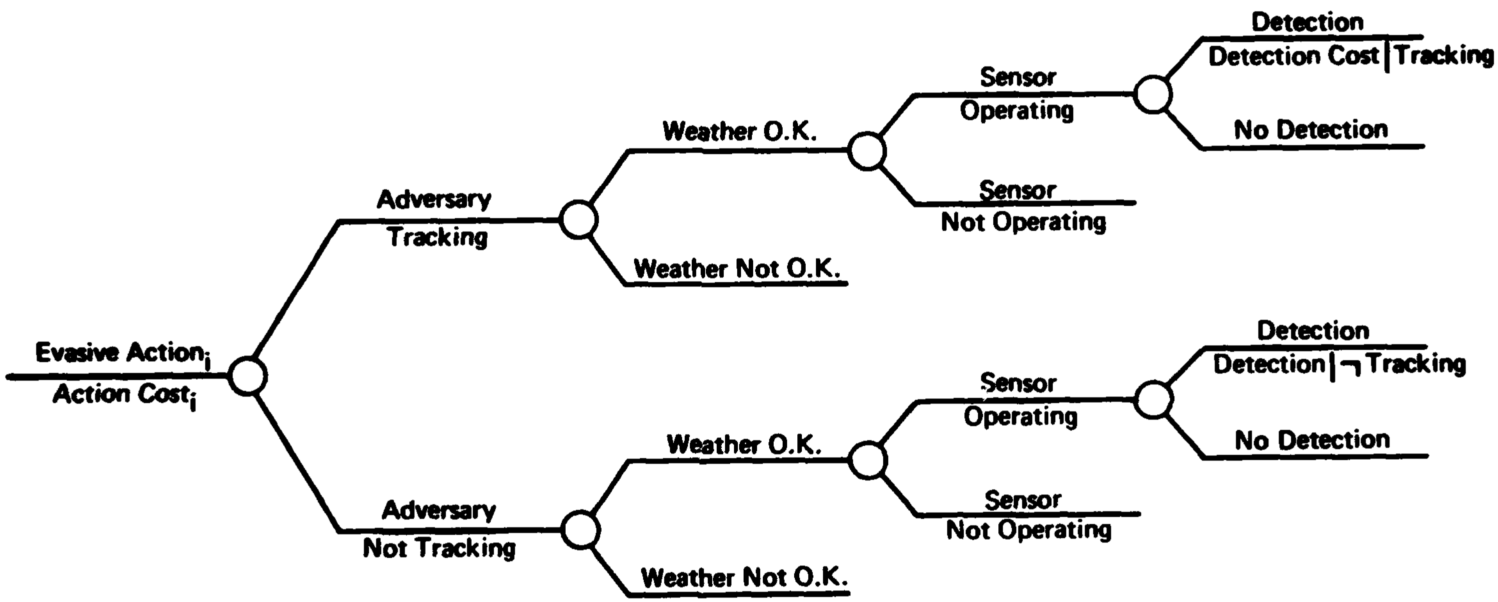


Figure 3-12

COMPLETE CONDITIONAL PROBABILITY STRUCTURE FOR EVALUATING NET COST OF EVASIVE ACTIONS

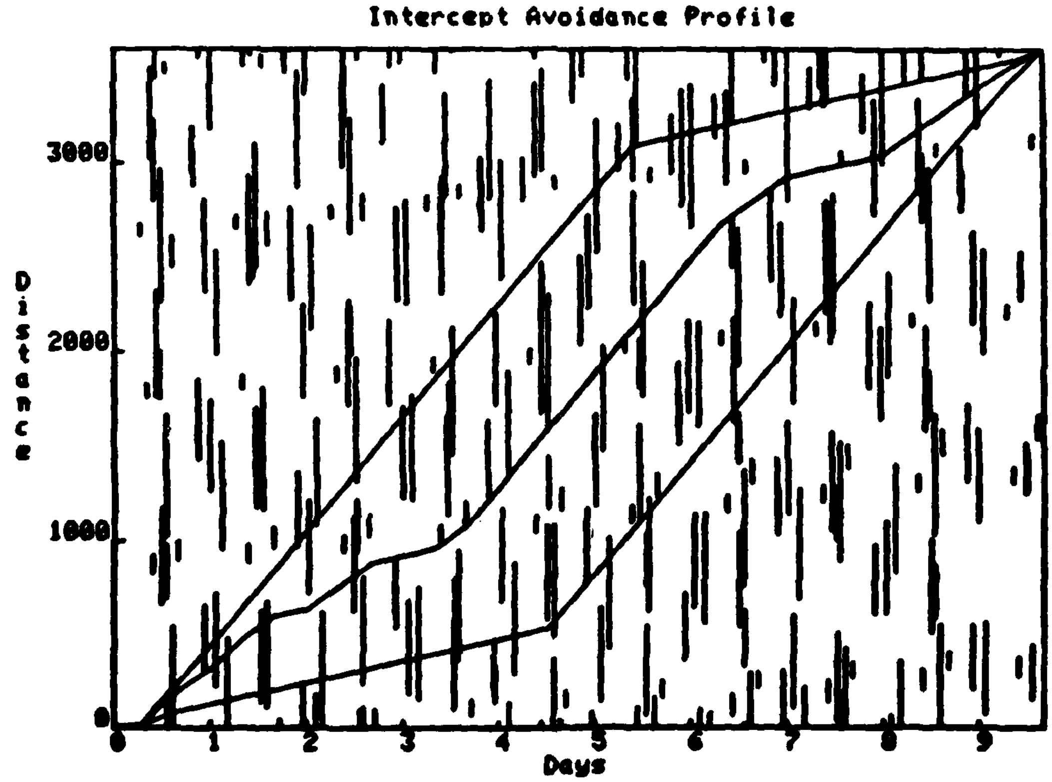
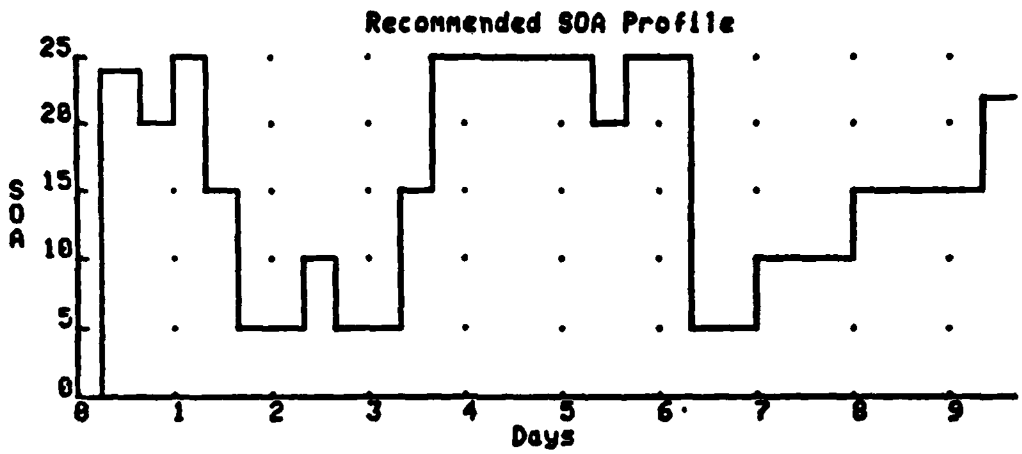


Figure 3-13
TIME-VERSUS-DISTANCE PLOT OF RECOMMENDED SOA PROFILE



Date-Time	SOA
17 NOV 0600	24
17 NOV 1600	20
18 NOV 0000	25
18 NOV 0800	15
18 NOV 1600	5
19 NOV 0000	5
19 NOV 0800	10
19 NOV 1600	5
20 NOV 0000	5
20 NOV 0800	15
20 NOV 1600	25
21 NOV 0000	25

Date-Time	SOA
21 NOV 0800	25
21 NOV 1600	25
22 NOV 0000	25
22 NOV 0800	20
22 NOV 1600	25
23 NOV 0000	25
23 NOV 0800	5
23 NOV 1600	5
24 NOV 0000	10
24 NOV 0800	10
24 NOV 1600	10
25 NOV 0000	15

Date-Time	SOA
25 NOV 0800	15
25 NOV 1600	15
26 NOV 0000	15
26 NOV 0800	22

Figure 3-14

STAGE-BY-STAGE PLOT OF RECOMMENDED SOA PROFILE VERSUS TIME

Detection Zones under Recm'd SOA Profile

No	ID	Lat	Lng	Date/Time	Expos	Action
1	E	37.4N	72.0W	17 NOV 1433	2.3	EMCON
2	I	37.6N	68.5W	17 NOV 2241	0.0	NORMAL OPERATIONS
3	C	37.7N	67.2W	18 NOV 0129	2.0	EMCON
4	C	37.8N	60.3W	19 NOV 0047	2.0	EMCON
5	C	37.7N	58.7W	19 NOV 1201	2.0	EMCON
6	E	35.0N	36.3W	22 NOV 0209	2.3	EMCON
7	E	33.9N	31.0W	22 NOV 1207	2.3	EMCON
8	O	31.0N	22.0W	23 NOV 1022	1.1	NORMAL OPERATIONS
9	O	30.7N	21.9W	23 NOV 2003	1.1	NORMAL OPERATIONS
10	C	31.1N	17.8W	24 NOV 2204	2.0	EMCON
11	C	32.3N	15.0W	25 NOV 0915	2.0	EMCON
12	E	34.0N	11.1W	25 NOV 2355	2.3	EMCON

Figure 3-15

DETECTION ZONE EVASIVE ACTIONS FOR THE RECOMMENDED SOA PROFILE

4.0 DESCRIPTION OF SYSTEM USE

This section describes the characteristics of the user interface portion of the Satellite Surveillance Avoidance Optimization Aid. It discusses the procedures for initiating and terminating execution of the Aid, the aspects of terminal operation which are relevant to use of the Aid, and the mechanisms employed for parameter specification and result display. The section is organized so that it may be used by itself as a users reference guide for operation of the Aid. Each significant feature is described in a separate subsection. Thus, a user desiring information about a particular feature can access the information easily by referring to the Table of Contents. On the other hand, the subsections are arranged in sequence and are related contextually to one another so that a user wanting an introduction to or a description of the complete Aid can satisfy his needs simply by reading this entire section.

To maintain consistency across feature descriptions, a single transit scenario is used throughout. In this scenario the task force is being routed as shown in Figure 4-1 from Norfolk, Virginia, to the Straits of Gibraltar by way of a point just to the northwest of the Canary Islands. The two legs of the journey--Norfolk to the Canaries and thence to Gibraltar--are along great circle routes. The course is diverted south to the Canary Islands to avoid a storm center presumed to lie along the more direct Norfolk-to-Gibraltar great circle route.

4.1 Initiation of Execution

The Aid consists of two primary software components, (1) the user interface software which executes in a Tektronix 4051 terminal and (2) the calculational software

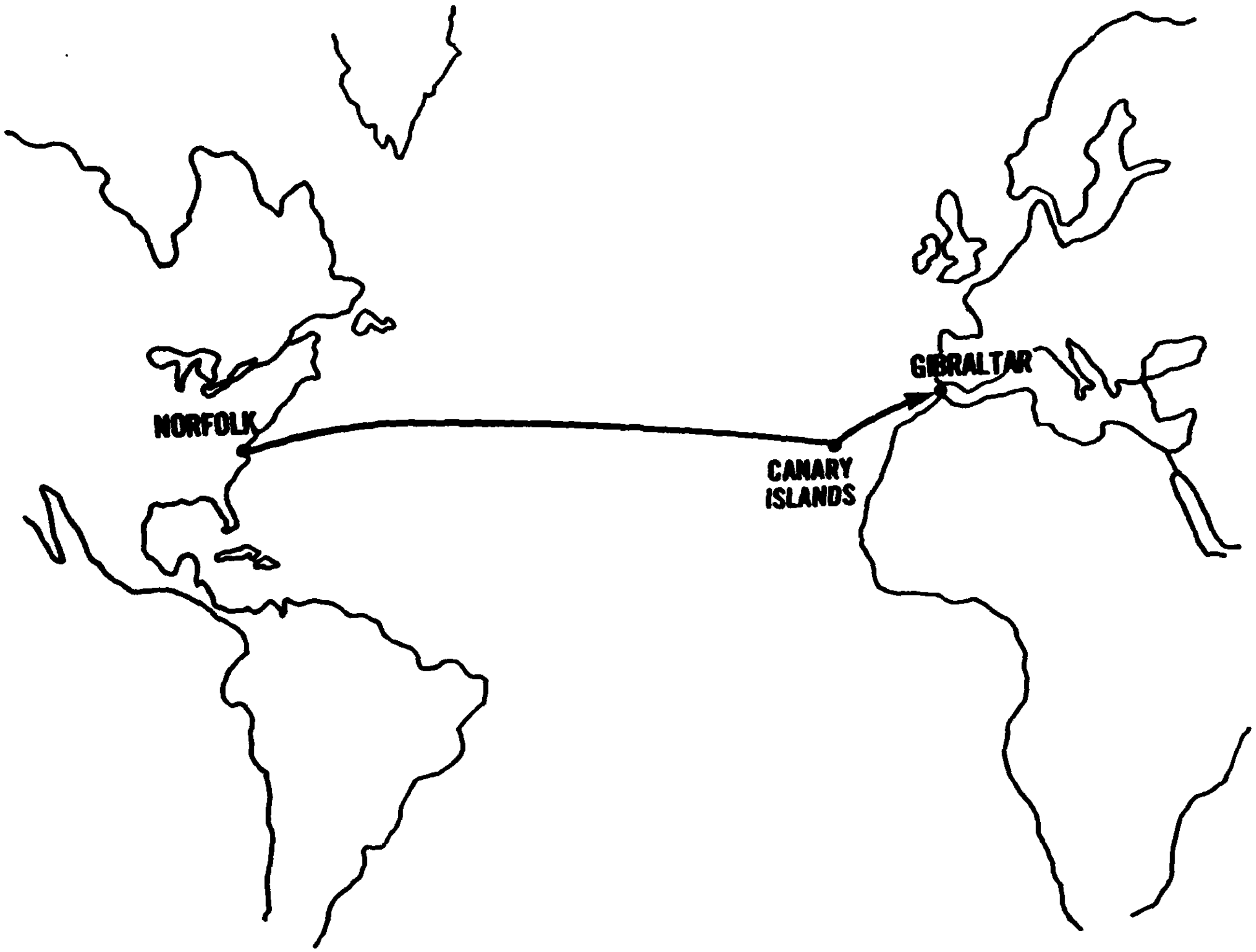


Figure 4-1
A HYPOTHETICAL TRACK PLAN FROM NORFOLK TO GIBRALTAR

which executes on a host computer. To initiate execution of the Aid, the user need be concerned only with the former.

The user interface software is stored on a magnetic tape cartridge which fits the tape cartridge drive of the 4051. The objective of the initiation procedure is simply to transfer the user interface software from the tape cartridge to the main memory of the 4051 and then to begin its execution. This may be accomplished by performing the following three steps:

Step 1. Turn 4051 power on.

Step 2. Insert the tape cartridge into the 4051 tape cartridge drive.

Step 3. Press the AUTO LOAD key.

(Refer to Figure 4-2 for the locations of the 4051 components involved in these steps). Once these steps have been performed, the user interface software will direct the user in the next action to be taken.

Each of the initiation procedure steps is described in more detail in the sections which follow.

4.1.1 <u>Step 1: Turn 4051 Power On</u> - The 4051 power switch is located beneath the right front edge of the keyboard, as shown in Figure 4-3. It is a rocker-type switch. To turn the power on, "rock" the switch to the right. To turn the power off, "rock" the switch back to the left.

When the power switch is turned on, the power indicator shown in Figure 4-3 will light up and the user should be able to hear the sound of the ventilation fan. If these conditions fail to occur, ensure that the power cable

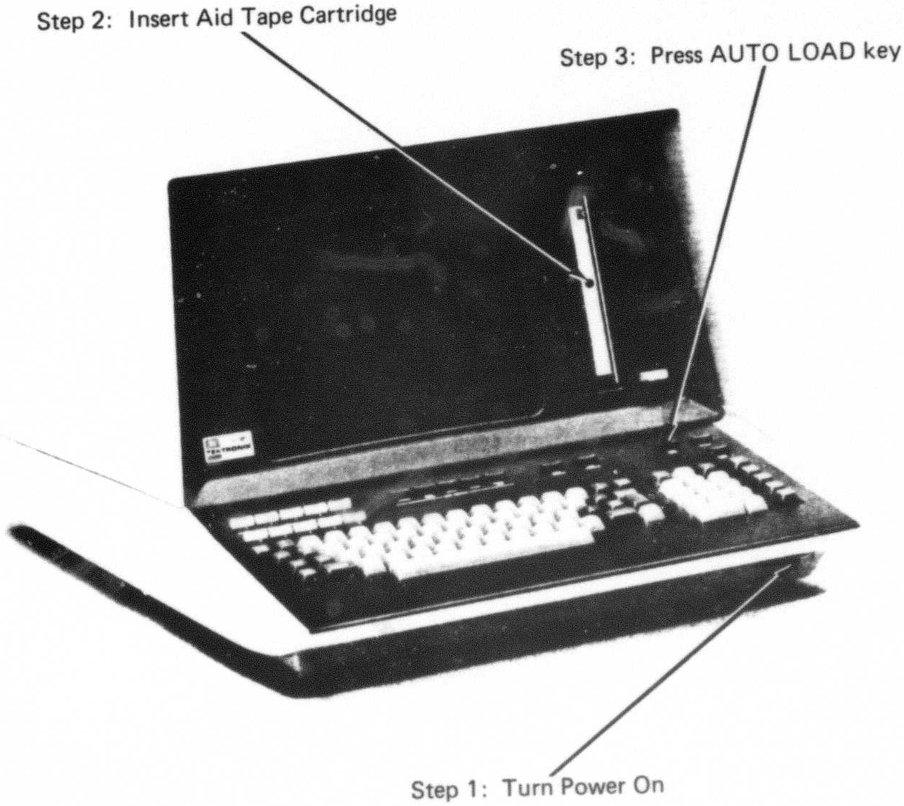


Figure 4-2
INITIATION OF EXECUTION — 4051 OPERATIONS

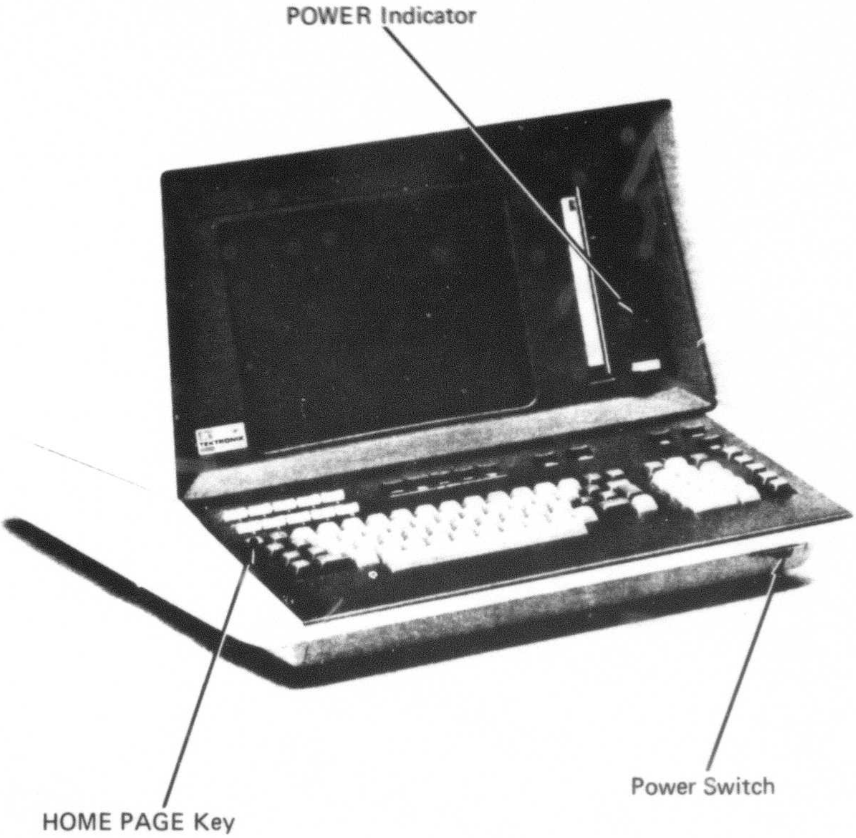


Figure 4-3
TURNING 4051 POWER ON

is inserted into a live outlet and is firmly inserted into the back of the 4051. If these checks are positive, the power line fuse may be blown. Otherwise, a more serious malfunction may be indicated, which would require the services of trained repair personnel.

A few seconds after power has been applied to the system, the screen will brighten so that it is uniformly illuminated. At this point the user may press the *HOME PAGE* Key (Figure 4-3) to clear the screen. This is not essential, however, since the user interface software will automatically clear the screen when it begins execution.

4.1.2 Step 2: Insert Aid Tape Cartridge - Once power has been applied to the 4051, insert the Aid tape cartridge into the tape cartridge drive. To do this, pick up the cartridge between thumb and fingers of the right hand so that the metal side of the cartridge is against the fingers and the tape label is closest to the hand. The clear plastic side of the cartridge should be against the thumb.

Insert the cartridge about one inch into the tape slot on the right side of the 4051 front panel, as shown in Figure 4-4a. The metal side of the cartridge should be toward the right side of the tape slot and the tape label should be out of the machine.

Release the cartridge; then place the thumb against the label edge of the cartridge and push it slowly into the tape slot. There should be very little mechanical resistance until the label edge of the cartridge projects about three-quarters of an inch beyond the front panel. At this point the EJECT button near the bottom of the tape slot (Figure 4-4b) will be flush with the front panel.

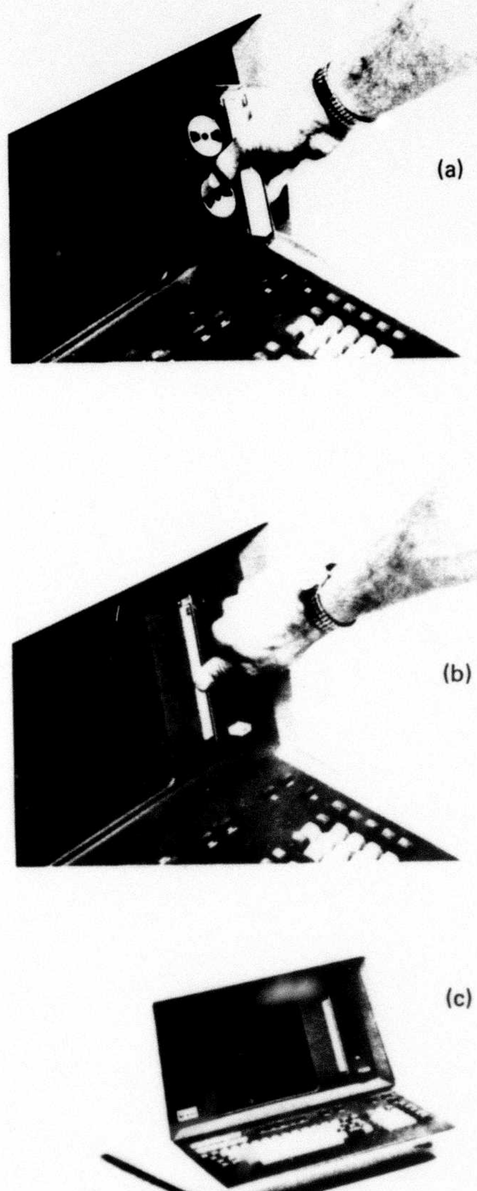


Figure 4-4
INSERTING A TAPE CARTRIDGE

Press slowly but firmly against the cartridge edge until the last three-quarters of an inch is pushed into the tape slot, as shown in Figure 4-4c. This will cause the EJECT button to emerge from the front panel. When the tape cartridge is properly seated in the tape slot, it will not be possible to push it in any further; the label edge of the tape cartridge will be flush with the front panel; and the EJECT button will protrude from the front panel about three-quarters of an inch.

4.1.3 <u>Step 3: Press AUTO LOAD Key</u> - Once the Aid tape cartridge has been inserted into the 4051 tape cartridge drive, press the AUTO LOAD key. This key is located near the back edge of the keyboard just below the tape slot, as shown in Figure 4-5.

Pressing the AUTO LOAD key causes the 4051 to rewind the tape (that is, to position the tape at its beginning if it is not already positioned there), then to load the user interface program from the tape into the 4051 main memory, and finally to initiate execution of the program. During this process, the green BUSY and I/O (input/output) indicators on the front panel (Figure 4-5) will be illuminated. Also, the 4051 tape drive will make a series of buzzing or scraping sounds, normal sounds that occur whenever the 4051 causes the tape to move. The AUTO LOAD process requires approximately 90 seconds.

When the tape movement stops, the screen will be erased (equivalent to pressing the PAGE key) and the image of Figure 4-6 will appear.

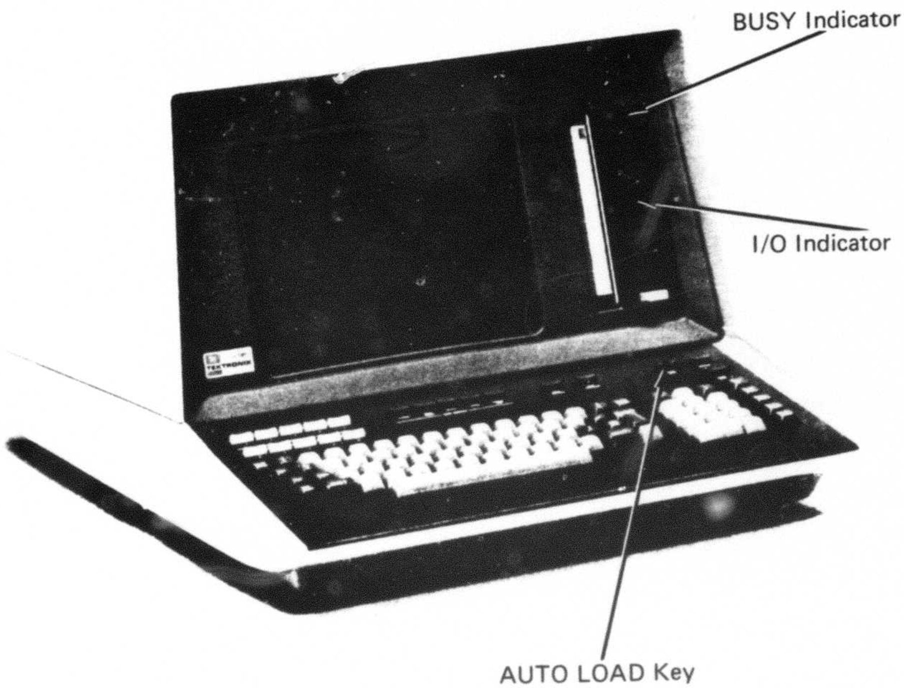


Figure 4-5
THE AUTO LOAD KEY

```
                Department of Defense
           Advanced Research Projects Agency
       (Information Processing Technology Office)

    SATELLITE SURVEILLANCE AVOIDANCE OPTIMIZATION AID

                     developed by
               Decisions & Designs, Inc.
OPTIONS:

(1)  Introduction
(2)  Define new transit plan
(3)  Review/edit old transit plan
(4)  Review old environmental parameters
(5)  Review old results
(6)  Stop execution

Enter number of option desired:
```

Figure 4-6

IMAGE PRESENTED TO USER WHEN AID EXECUTION BEGINS

4.2 Terminal Operation

At various stages in the operation of the Aid the user will be required to take certain specific actions with the keyboard. The particular action to be taken at each point will be discussed in the sections devoted to the features requiring user responses. However, there are a number of generic issues pertaining to keyboard and terminal operation which will be discussed here to avoid describing them redundantly below and to provide a centralized source for the information.

4.2.1 <u>Functional Layout and Use of the Keyboard</u> - As shown in Figure 4-7, the 4051 keyboard can be viewed as consisting of six logically distinct sets of keys:

- Alphanumeric Keyboard
- Numeric Pad and Math Function Keys
- User Definable Keys
- Line Editor Keys
- Program Statement Keys
- Tape and Hard Copy Controls

Of these sets of keys only the Alphanumeric Keyboard, the Numeric Pad, the Line Editor Keys, and the Tape and Hard Copy Controls should be used to interact with the Aid.

The User Definable Keys are not currently supported by the Aid and are in fact deactivated by the program when it is executing. The Program Statement Keys are used for programming purposes only and have no effect when used in conjunction with execution of the Aid.

<u>Alphanumeric Keyboard</u>

As a practical matter, virtually all user interactions with the Aid can be accomplished with the Alphanumeric Keyboard alone. The light grey keys (including the space bar) augmented by the dark grey SHIFT keys allow the user to type all the characters (letters, numbers, and symbols) customarily available on a standard typewriter. These keys are sufficient to compose all keyboard responses required by the Aid. All other keys (including those in other functional groups)

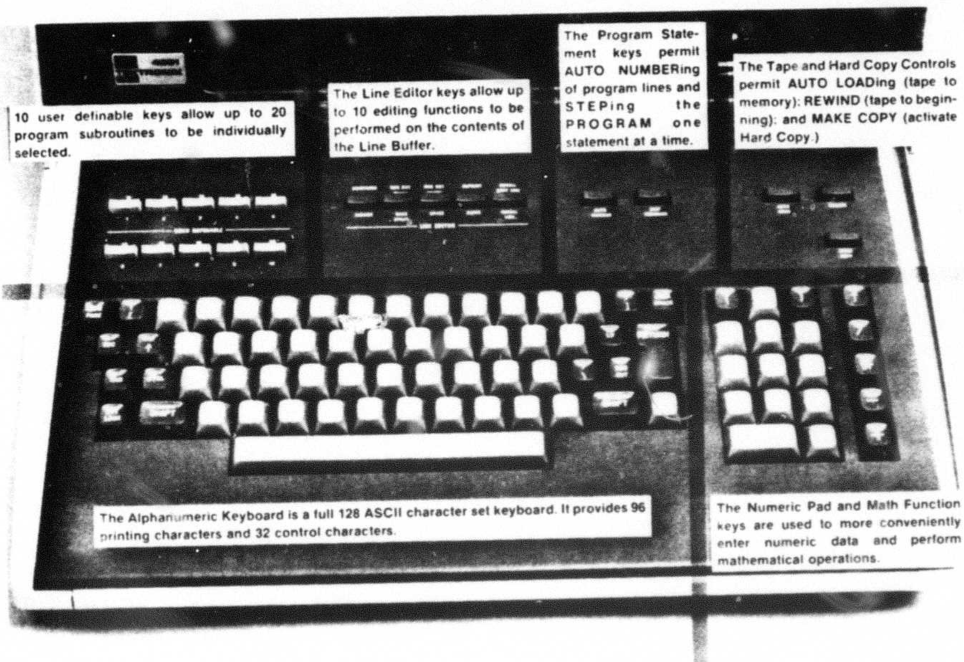


Figure 4-7

4051 KEYBOARD LAYOUT

merely provide alternatives to these keys or provide means for altering or editing erroneous entries.

The Aid will accept either uppercase or lowercase letters in response to any query. Thus, "YES" and "yes" will be equivalent.

Once the user has composed his entry and is satisfied with its correctness, he must signal this fact to the program by pressing the RETURN key. This fact should be emphasized, since it is the step most often overlooked by the computer-naive user.

Other Alphanumeric Keyboard Keys which are useful for interacting with the Aid include:

- TTY LOCK — Pressing this key (to "lock" it) causes all alphabetic characters to appear as uppercase characters, regardless of the state of the SHIFT key. The key must be pressed again to release it.

- HOME PAGE — Pressing this key by itself (the PAGE function) causes the display to be erased. Pressing this key in combination with the SHIFT key (the HOME function) causes the cursor (discussed below) to move to the upper left corner of the screen, the home position, but does not erase the screen.

- BACKSPACE — Pressing this key causes the cursor (discussed below) to move to the

left one character space but does not affect the character currently displayed in that position.

- o RUBOUT — Pressing this key causes the cursor (discussed below) to move to the left one character space and overwrites any character currently displayed in that position with a solid rectangle. The character under the cursor is replaced by the SPACE character. (If the cursor is initially positioned over a character, pressing the RUBOUT key deletes that character. Subsequent activations of the key affect characters to the left).

Note that most keys repeat their respective functions whenever they are held down for more than about a half second.

The SPACE bar, the BACKSPACE key, and the RUBOUT key can be used to change or edit an entry before it is "sent" to the program with the RETURN key. The SPACE and BACKSPACE keys allow the cursor to be moved back and forth along a typed entry. Any character under the cursor can be replaced simply by typing the replacement character. (Both the new and the old characters will appear, overwritten, on the screen, but the old character will have been replaced by the new character in the entry seen by the program). The RUBOUT key allows the user to delete any unwanted characters.

The remaining keys on the Alphanumeric Keyboard are normally not required by and should not be used in conjunction with the Aid. These keys are the following: ESC, TAB, CTRL, BREAK, the two bracket-character keys, the up-arrow key, the back-slash key, and the LF (line feed) key.

The use (accidental or intentional) of any of these keys will not in general be disastrous but may result in unwanted characters appearing in an entry. The worst situation arises when the BREAK key has been activated; this will cause program execution to be suspended.

BREAK Key

Accidental activation of the BREAK key can be remedied in the following manner. If the BREAK key has been depressed once, the BREAK indicator on the 4051 front panel (Figure 4-8) will light up and program execution will stop after the program statement currently in process has finished. If the user is in the process of typing an entry, he may complete that operation (through the step of pressing RETURN) with no ill effect. At that point the BREAK indicator will go out and the 4051 will display a message of the form:

PROGRAM INTERRUPTED PRIOR TO LINE nnnn
where nnnn represents a line number. The program may be restarted from the point at which it was interrupted simply by typing "RUN," followed by the line number nnnn, then pressing RETURN:

RUN nnnn

If the BREAK key has been depressed twice in rapid succession or a second time while the BREAK indicator is lighted, program execution will be aborted immediately and the 4051 will display a message of the form:

PROGRAM ABORTED IN LINE nnnn

In this case the program must be restarted from the beginning; it may not be restarted from the point at which it was aborted else undesirable behavior may result. To

Figure 4-8
BREAK INDICATOR

restart from the beginning, either type "RUN" or press the AUTO LOAD key. However, if communication with the host has been established previously (see Section 4.2.4), then other steps must be taken before typing "RUN" or pressing AUTO LOAD in order to ensure synchronization of host program execution and terminal program execution. In particular, the user must take the following actions:

(1) Type 'CALL "TERMIN"' (then press the RETURN key). Note that the double-quote marks are part of the character string that must be typed.

(2) Depress the CTRL key and simultaneously press the letter C key. At this point the host computer may respond by printing a message or some other characters; the last thing to appear should be a period on a line by itself.

(3) Press User Definable Key number 5. If the User Definable Keys are covered by a Data Communication Interface template, key number 5 will be labeled "RETURN TO BASIC."

Only after this sequence of steps has been taken should the user type "RUN" or press AUTO LOAD.

As mentioned above, the Numeric Pad, the Line Editor Key, and the Tape and Hard Copy Controls generally duplicate functions which can be performed using the Alphanumeric Keyboard. Many of these keys do facilitate certain operations, however, so they are worth discussing. (In fact, a few of the functions provided by these keys can be performed from the Alphanumeric Keyboard only in a circuitous manner).

Numeric Pad

All of the keys in the Numeric Pad duplicate keys appearing in the Alphanumeric Keyboard. However, use of these keys for numeric data entry may be preferred by users familiar with the standard calculator keyboard. (None of the Math Function Keys is ever required for responses required by the Aid).

Line Editor Keys

The Line Editor Keys may be useful to change or edit any user-typed entry (before RETURN has been pressed). There are five keys, each of which has two functions. The function listed below each key is selected by pressing the key alone; the function listed above is selected by pressing the key in combination with the SHIFT key. Of the ten possible functions, only eight are operable for editing entries to the program; the RECALL LINE and RECALL NEXT LINE functions are used for programming purposes only. The other functions are used as follows:

- EXPAND — This function causes all characters to the right of the cursor, including the character under the cursor, to be moved to the extreme right of the screen. The user's entry will appear split into left and right portions separated by a gap. The cursor remains at the extreme left of the gap, in position for additional characters to be inserted.

- COMPRESS — This function acts as the inverse of EXPAND. The gap between the

cursor and the right portion of the entry is closed by shifting the right portion to the current position of the cursor.

- o BACKSPACE — This function duplicates the BACKSPACE key of the Alphanumeric Keyboard; the cursor moves one character position to the left.

- o RUBOUT $\leftarrow$ — This function duplicates the RUBOUT key of the Alphanumeric Keyboard; the character under the cursor (or to its left) is deleted.

- o SPACE — This function duplicates the SPACE bar of the Alphanumeric Keyboard; the cursor moves one character position to the right.

- o RUBOUT $\rightarrow$ — This function is equivalent to the RUBOUT key of the Alphanumeric Keyboard except that the cursor moves to the right instead of left. The character under the cursor, or to its right, is deleted.

- o CLEAR — This function totally erases or clears away the user entry. This is useful when the entry has become so garbled from editing that the user would like to start fresh.

- o REPRINT — This function causes the current entry to be displayed again one line down. This is useful when the

entry has been edited and contains rubouts and typeovers, and the user would like to see a "clean" copy before pressing RETURN.

<u>Tape and Hard Copy Controls</u>

The Tape and Hard Copy Controls are used to request three common tape drive and hard copy unit operations. The functions provided by these keys are:

- AUTO LOAD — As discussed above, this function is used to load the Aid from a tape cartridge into the main memory of the 4051 and to begin its execution.

- REWIND — This function causes the 4051 tape cartridge drive to position the tape at its beginning. Use of this function in conjunction with the Aid is not required.

- MAKE COPY — This function causes a hard copy unit attached to the 4051 to make a paper copy of the image appearing on the display screen.

4.2.2 <u>Display features</u> - There are several features of the 4051 display screen which are often sources of puzzlement or consternation to the user unfamiliar with Tektronix display devices. The most significant of these include:

- reduced display intensity;

- automatic erasing of the screen;

- different cursors;
- page-full condition.

Each of these will be discussed in turn.

Reduced Intensity

As information is displayed upon the screen, its intensity (though not overly bright) is sufficient to permit normal viewing. As long as information continues to be added to the display image or the 4051 is actively processing data, the data displayed upon the screen will continue to remain visible. However, should all activity in the 4051 cease for a period of about 90 seconds (while waiting for the user to begin to type a response to a program query, for instance), the display image will automatically reduce in intensity so that it is no longer (or at best, scarcely) visible. In this reduced intensity level the image remains stored upon the screen, but is dimmed. Any activity in the 4051 will reestablish the normal viewing intensity so that the information will again be visible. The customary way to reestablish normal intensity is to press the SHIFT key. Pressing any other key will have the same effect, but pressing SHIFT has the advantage that it does not by itself generate any input data to the program. This makes it a convenient way to reestablish normal intensity. (The reduced intensity is a design feature intended to prolong display screen life.)

Automatic Erasing

Another feature aimed at prolonging screen life is the automatic erasing feature. If there has been no activity in the 4051 for a period of about 30 minutes, the display screen is automatically erased as if the PAGE key were

pressed. This protects the screen from damage when the 4051 has been inadvertently left on and unattended. This is unlikely to occur in use of the Aid (unless the user goes to lunch in the middle of a session), but if it does, the Aid will almost certainly be waiting for the user to respond to a query. Since the screen will be blank, the user will have no idea of what response is expected. The easiest way to circumvent this problem is to press the RETURN key alone. This will be an invalid response to all queries. The Aid will inform the user of this fact and will then repeat the query.

Cursors

A more subtle potential source of confusion arises from the fact that the 4051 can display different types of cursors. Only two of the cursor types are likely to appear when the Aid is being used, but the user should know their significance.

Under all normal conditions in use of the Aid, a cursor will appear upon the screen only when the user is expected to respond to a program query. In this case the cursor will appear as a blinking question mark and marks the position on the screen at which a character typed from the keyboard will appear. Thus, a blinking question mark indicates that it is the user's turn to take an action. (This should be obvious from the context of information displayed upon the screen.)

In a few other situations the cursor will appear as a blinking solid rectangle. Under normal conditions in use of the Aid, the rectangular cursor should appear only when power is first applied to the 4051 before the AUTO LOAD key is pressed (see Section 4.1) and when the "Execution terminated" message has been displayed (see Section 4.9). If this cursor appears at any other time, it indicates that

program execution has been interrupted abnormally, such as by pressing the BREAK key. In this event program execution must be resumed or restarted as described for the BREAK key in Section 4.2.1.

Page-Full Condition

In a few situations when the user is providing inputs to the Aid, the cursor may move off the bottom of the screen. This will happen when the user types an entry on the last line at the bottom of the screen and then presses RETURN. When this occurs, the cursor will disappear, any information typed by the user after pressing RETURN will not be displayed, and a blinking "F" will appear in the extreme upper left corner of the screen, the "home" position. This is called the "page-full condition."

The page-full condition does not entirely inhibit 4051 operation, but for all practical purposes the Aid will stop its processing until the condition is alleviated. This may be accomplished simply by pressing the PAGE key to clear the screen. Aid execution will then continue.

4.2.3 Tape cartridge involvement - The Aid tape cartridge contains a permanent copy of the user interface software and, as discussed in Section 4.1, is used to initialize the 4051 main memory whenever the Aid is to be used. The tape cartridge is involved in more than just the initialization process, however. In fact, the user interface software consists of several pieces which are stored on the tape and which are selectively brought into main memory to replace other pieces, depending upon the particular function presently required by the user (such as parameter specification or result display).

The significance of this fact is that the tape cartridge must remain in the 4051 tape cartridge drive the whole time the Aid is in use. If the tape cartridge has been removed from the drive, the 4051 will cease execution of the Aid and will display the following message on the screen whenever a new piece of the program is needed:

MAG TAPE CARTRIDGE REQUIRED IN LINE nnnn - MESSAGE NUMBER 57

When this occurs, the Aid tape cartridge must be reinserted into the tape drive and the program must be restarted from the beginning. To restart the program, the user can press AUTO LOAD or he can simply type "RUN."

In addition to containing the user interface software, the tape cartridge is used by the Aid to store parameter and result values. This enables the user to retrieve and to manipulate the values produced in an earlier session or to interrupt a session and to resume where he left off some hours or days later. Furthermore, it minimizes the amount of 4051 main memory taken up for data storage by allowing values not required for immediate processing to be removed from the memory.

Storage of data values on the tape cartridge is another reason that the cartridge must remain in the 4051 tape drive while the Aid is in use. Another constraint that this imposes upon the cartridge is that it must <u>not</u> be placed in a write-protected state; the arrow on the write-protect cylinder must point <u>away</u> from the word SAFE, as shown in Figure 4-9. Whereas loading program pieces from the tape involves only reading of information, storing data involves writing data on the tape as well.

If the cartridge has been write-protected, the 4051 will cease execution of the Aid and will display the

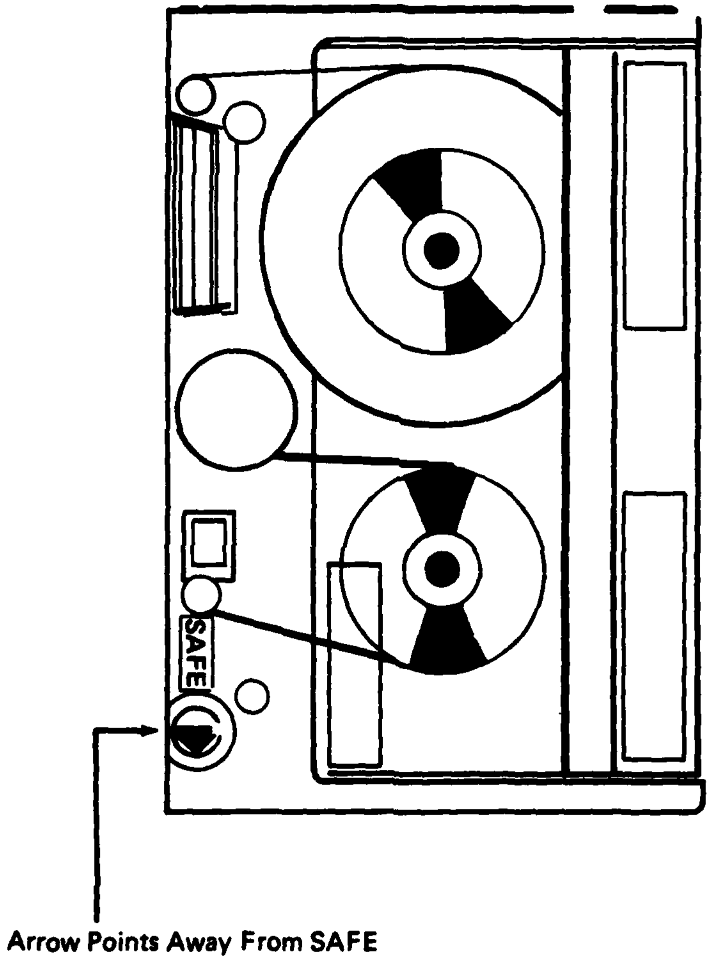


Figure 4-9
TAPE CARTRIDGE NOT WRITE-PROTECTED

following message whenever any attempt to change data values on the tape is made:

MAG TAPE IS WRITE PROTECTED IN LINE nnnn - MESSAGE NUMBER 56

As when the tape cartridge has been removed, the program must be restarted from the beginning, either by pressing AUTO LOAD or by typing "RUN."

4.2.4 Host computer involvement - As mentioned in Section 4.1, the Aid consists of two primary software components: (1) the user interface software and (2) the calculational software. The user interface software resides and executes solely in the Tektronix 4051 terminal. The calculational software, which performs satellite intercept and optimization calculations, is much too taxing for the 4051 in terms of memory requirements and computational complexity. Therefore, it has been installed in a larger, faster "host" computer with which the 4051 communicates. The 4051 elicits parameter values from the user (via the user interface software) and sends them to the host. The host uses these values in its calculations and in turn sends result values back to the 4051 for display to the user.

For the most part the user need not concern himself with the details of this arrangement. However, when the 4051 is ready to begin its dialogue with the host, the user must ensure that a communication path exists between it and the 4051. Thus, before the 4051 conducts its initial "handshaking" with the host, the user may be asked to establish a telephone connection with the host unless a hard-wired connection already exists. The details of this request are discussed in Sections 4.6.1 and 4.7.1.

4.3 Primary Options

When execution of the Aid begins, and at various other stages during its execution, the user is presented with a screen image such as the one in Figure 4-10 containing the name, or title, of the Aid and a list of options from which the user is expected to select. The options presented on this "title page" represent the primary classes of activities which the Aid will support for specifying and reviewing parameter values and examining results.

```
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           Advanced Research Projects Agency
        (Information Processing Technology Office)

     SATELLITE SURVEILLANCE AVOIDANCE OPTIMIZATION AID

                      developed by
                 Decisions & Designs, Inc.

OPTIONS:

(1)  Introduction
(2)  Define new transit plan
(3)  Review/edit old transit plan
(4)  Review old environmental parameters
(5)  Review old results
(6)  Stop execution

Enter number of option desired:
```

Figure 4-10

The list of options on the title page will appear in three slightly different forms as a function of where the user is in the sequence of planning a transit. If the user defined a transit completely and calculated its results before terminating execution in his last session with the Aid, the title page options will appear as shown in Figure 4-10. If the user either has defined a new transit plan or has made changes to a previous transit plan but has not requested result calculation, the title page options will appear as shown in Figure 4-11. Finally, if the user has just completed result calculation, or if he has reviewed old parameters or results but made no changes, the title page options will appear as shown in Figure 4-12. The significance of each of these title pages will be discussed below. The details of each option are discussed in Sections 4.4 through 4.9.

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SATELLITE SURVEILLANCE AVOIDANCE OPTIMIZATION AID

developed by
Decisions & Designs, Inc.

OPTIONS:

(1) Introduction
(2) Define new transit plan
(3) Review/edit transit plan
(4) Review environmental parameters
(5) Calculate results
(6) Stop execution

Enter number of option desired:

Figure 4-11

```
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              Advanced Research Projects Agency
          (Information Processing Technology Office)

     SATELLITE SURVEILLANCE AVOIDANCE OPTIMIZATION AID

                        developed by
                  Decisions & Designs, Inc.
OPTIONS:

(1)  Introduction
(2)  Define new transit plan
(3)  Review/edit transit plan
(4)  Review environmental parameters
(5)  Review results
(6)  Stop execution

Enter number of option desired:
```

Figure 4-12

4.3.1 Options given Previously Calculated Results - The title page options shown in Figure 4-10 will be presented to the user as execution of the Aid first begins if the user's last session ended after the results for a transit had been calculated. The review options, items 3 through 5, all indicate that the parameters and results of an "old," previously calculated transit are available for examination. The word "old" in these items is simply a reminder that the last transit results are still available for review.

If the user actually reviews some results or parameters (by selecting one of options 3 through 5), the word "old" will not be displayed in subsequent instances of the title page; instead the image of Figure 4-12 will appear.

If the user changes--edits--any transit plan parameters or defines an entirely new transit plan, the image of Figure 4-11 will appear.

4.3.2 Options given a New or Revised Transit Plan - Regardless of which title page option list was previously in effect, if the user edits transit plan parameters or defines a new transit plan, the title page of Figure 4-11 will appear. Option 5 indicates that before results for the new current transit plan can be reviewed, they must be calculated; previously calculated results are no longer available. Once option 5 has been exercised by the user, the title page of Figure 4-12 will become effective.

4.3.3 Options given Newly-Calculated Results - After the user causes results for a new or a revised transit plan to be calculated, he will be presented with the title page of Figure 4-12. He will be presented with this title page if he selects any of the review options of the title page in Figure 4-10, as well.

The title page of Figure 4-12 will remain effective until the user edits a parameter or defines a new transit plan; it will then revert to the title page of Figure 4-11.

4.3.4 Introduction Option - The first option, "Introduction," on each of the three title page option lists (Figures 4-10, 4-11, and 4-12) is not currently implemented but is provided for future convenience.

If the user selects this option by typing a "1" when asked to "Enter number of option desired:", the Aid will respond by displaying the phrase "No introduction--press RETURN..." as shown in Figure 4-13.

```
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        SATELLITE SURVEILLANCE AVOIDANCE OPTIMIZATION AID

                        developed by
                   Decisions & Designs, Inc.

OPTIONS:

(1)  Introduction
(2)  Define new transit plan
(3)  Review/edit old transit plan
(4)  Review old environmental parameters
(5)  Review old results
(6)  Stop execution

Enter number of option desired:  1
No introduction--press RETURN...
```

Figure 4-13

As soon as the user presses RETURN, the Aid will clear the screen and display the current title page again.

4.4 Transit Plan Definition

If the user selects the "Define new transit plan" option by typing a "2" when the title page appears (Figure 4-14), the Aid will begin a transit plan definition sequence. This option may be selected from any one of the three title pages (Figures 4-10, 4-11, and 4-12).

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SATELLITE SURVEILLANCE AVOIDANCE OPTIMIZATION AID

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Decisions & Designs, Inc.

OPTIONS:

(1) Introduction
(2) Define new transit plan
(3) Review/edit old transit plan
(4) Review old environmental parameters
(5) Review old results
(6) Stop execution

Enter number of option desired: 2

Figure 4-14

In the transit plan definition sequence the Aid asks the user to specify values for a number of parameters which describe the transit plan. These parameters are the following:

- Departure and arrival times
- Track plan (point of departure, destination, and intermediate points)
- Probability of already being tracked at departure
- SOA options
- Time increment for SOA changes

- Fuel costs
- Detection aversion costs
- Evasive action costs

The elicitation process and sequence for transit plan definition is described in the subsections below.

4.4.1 Departure and Arrival Times - When the transit plan definition sequence begins, the Aid asks the user to specify his desired departure time and date as shown in Figure 4-15. The user should format his response according to the example provided and as shown in Figure 4-16.

Spaces are required between time and day, day and month, and month and year. Leading zeros are not required for any field, but are permitted; thus, 6 o'clock in the morning may be specified as either "0600" or "600" and the fourth day of the month may be specified as either "04" or "4".

Time must be specified in the twenty-four hour system, from 0000 to 2400, and is assumed to be Greenwich mean time. The month must be specified by name (not as a number) but may be abbreviated to the first three characters of the name. The year may be specified in its entirety (e.g., "1977") or may be abbreviated to the last two digits (e.g., "77").

When the user presses RETURN to terminate his entry, the Aid reprints the entry, reformatted if necessary, and the user is asked to confirm its correctness as shown in Figure 4-17. If the value is correct, the user may confirm it by typing either "YES" or simply "Y"; any other response, including RETURN by itself, is interpreted to mean no. A

```
TRACK PLAN SPECIFICATION                                        Value Entered

Enter desired departure time & date--
     (e.g., 0800 16 July 77):
```

Figure 4-15

```
TRACK PLAN SPECIFICATION                                        Value Entered

Enter desired departure time & date--
     (e.g., 0800 16 July 77):  0600 17 nov 77
```

Figure 4-16

```
TRACK PLAN SPECIFICATION                                        Value Entered

Enter desired departure time & date--
     (e.g., 0800 16 July 77):  0600 17 nov 77              0600 17 NOV 77
Is this value correct?  yes

Enter desired arrival time & date--
     (e.g., 1430 25 July 77):  1600 26 nov 77              1600 26 NOV 77
Is this value correct?  y
```

Figure 4-17

negative response causes the Aid to ask for the value again; an affirmative response causes the Aid to ask for the next parameter value, desired arrival time, as shown in Figure 4-17.

Arrival time and date must be specified in the same manner as departure time and date. The Aid checks to ensure that departure precedes arrival and gives the user an opportunity to correct a discrepancy, if it occurs.

4.4.2 Track Plan - Following the requests for departure and arrival times, the Aid asks the user to specify the route, or track plan, which he expects to follow. The Aid first asks the user to specify the latitudes and longitudes of his point of departure and his destination. This operation is illustrated by Figure 4-18.

```
TRACK PLAN SPECIFICATION                                        Value Entered

Enter desired departure time & date--
     (e.g., 0800 16 July 77):  0600 17 nov 77                  0600 17 NOV 77
Is this value correct?  yes

Enter desired arrival time & date--
     (e.g., 1430 25 July 77):  1600 26 nov 77                  1600 26 NOV 77
Is this value correct?  y

Enter point-of-departure latitude:   36 54 n                    36 54 00 N
Is this value correct?  y

Enter point-of-departure longitude:  76 18 w                   076 18 00 W
Is this value correct?  y

Enter destination latitude:   35 57 n                           35 57 00 N
Is this value correct?  y

Enter destination longitude:  5 36 w                           005 36 00 W
Is this value correct?  y
```

Figure 4-18

Each latitude or longitude must be specified in degrees, minutes, and seconds, although minutes and seconds need not be specified if they are zero. Spaces are required between fields (between degrees and minutes, etc.). Leading zeros are not required for any field but are permitted.

Direction--north or south for latitude, east or west for longitude--must be specified and must be entered as a single character.

The user is given a chance to review each value entered and must confirm its correctness. Values which are not confirmed as correct are requested again.

For the example shown in Figure 4-18 the point of departure is Norfolk, Virginia, and the destination is Gibraltar. Normally, the Aid assumes that the route to be traveled between point of departure and destination lies along a great circle. Through the dialogue presented in Figure 4-19, the Aid allows the user to deviate from a simple great circle path by specifying up to eight intermediate points. In this example a single intermediate point near the Canary Islands has been specified. Whenever a segmented route is specified in this manner, the Aid assumes that each segment lies along a great circle.

When more than one intermediate point is desired. the points must be specified in the sequence to be traveled, from point of departure to destination. The syntax for specifying intermediate-point latitudes and longitudes is the same as that for point of departure and destination.

If the number of intermediate points is sufficiently great or if several value corrections are made in the course of track plan specification, the page-full condition discussed in Section 4.2.2 may occur. The user

TRACK PLAN SPECIFICATION	Value Entered
Enter desired departure time & date-- (e.g., 0800 16 July 77): 0600 17 nov 77 Is this value correct? yes	0600 17 NOV 77
Enter desired arrival time & date-- (e.g., 1430 25 July 77): 1600 26 nov 77 Is this value correct? y	1600 26 NOV 77
Enter point-of-departure latitude: 36 54 n Is this value correct? y	36 54 00 N
Enter point-of-departure longitude: 76 18 w Is this value correct? y	076 18 00 W
Enter destination latitude: 35 57 n Is this value correct? y	35 57 00 N
Enter destination longitude: 5 36 w Is this value correct? y	005 36 00 W
Are intermediate points desired? y Enter number of intermediate points desired: 1	
Enter latitude for point 1: 30 n Is this value correct? y	30 00 00 N
Enter longitude for point 1: 20 w Is this value correct? y	020 00 00 W

Figure 4-19

should be alert to this possibility. The page-full condition may be alleviated by pressing the PAGE key.

4.4.3 Probability of Already Being Tracked - When the track plan specification has been completed, the Aid will ask the user to estimate the probability of already being tracked as he leaves his point of departure. This is shown in Figure 4-20. The user's response must be a number between 0 and 1. If less than 1, the number must contain a decimal point; a zero to the left of the decimal point is optional.

If there is exactly one intermediate point in the track plan or if several value corrections have been made in the course of track plan specification, the page-full condition discussed in Section 4.2.2 may occur during the probability elicitation process. This is the case for the example shown in Figure 4-20. Pressing the PAGE key to clear the page-full condition will cause the image of Figure 4-21 to appear. The message

Press RETURN to continue...

indicates that the first phase of the transit plan definition sequence is complete. (The message does not appear as a result of clearing the page-full condition. It is a normal part of the elicitation process.) Pressing the RETURN key at this point causes the screen to be cleared and initiates the next phase of the transit plan definition sequence. The pause provided by the "Press RETURN..." message allows the user to review any information which might be on the screen (as would be the case if there were fewer or more intermediate points than appear in the example of Figures 4-20 and 4-21) before beginning the next phase.

4.4.4 SOA Options - The second phase of the transit plan definition sequence begins with the selection of the

TRACK PLAN SPECIFICATION	Value Entered
Enter desired departure time & date-- (e.g., 0800 16 July 77): 0600 17 nov 77 Is this value correct? yes	0600 17 NOV 77
Enter desired arrival time & date-- (e.g., 1430 25 July 77): 1600 26 nov 77 Is this value correct? y	1600 26 NOV 77
Enter point-of-departure latitude: 36 54 n Is this value correct? y	36 54 00 N
Enter point-of-departure longitude: 76 18 w Is this value correct? y	076 18 00 W
Enter destination latitude: 35 57 n Is this value correct? y	35 57 00 N
Enter destination longitude: 5 36 w Is this value correct? y	005 36 00 W
Are intermediate points desired? y Enter number of intermediate points desired: 1	
Enter latitude for point 1: 30 n Is this value correct? y	30 00 00 N
Enter longitude for point 1: 20 w Is this value correct? y	020 00 00 W
Enter probability of already being tracked at departure (0.00-1.00): .05 Is this value correct? y	.05

Figure 4-20

Press RETURN to continue...

Figure 4-21

SOA options to be considered in the optimization process. The user is first presented with a set of default SOA options as shown in Figure 4-22. The only significance to be associated with these options is that they are meant to represent what may be commonly used speeds. The user is completely free to define his own set of options, which he can do by responding affirmatively to the question posed in Figure 4-22.

If the user indicates his desire to specify SOA options different from the defaults, he is asked to do so by providing a minimum value, a maximum value, and an increment, as shown in Figure 4-23. Although the example shows these values to be multiples of 5, this is not a requirement; the only restriction is that the minimum SOA and the maximum SOA must be multiples of the SOA increment. The minimum SOA may in fact be zero or negative. Fractional values are not permitted, however.

Once the user provides the values requested in Figure 4-23, the Aid checks them for consistency, requests changes if inconsistencies are found, and asks the user to confirm the correctness of his choices as shown in Figure 4-24.

4.4.5 <u>Time Increment for SOA Changes</u> - Following the specification of SOA options, the Aid asks the user to select a time increment to be used in the optimization process as the length of time over which SOAs will be maintained. This request is illustrated in Figure 4-25. When a particular SOA value is chosen by the optimizer, the user is expected to maintain that speed for this task force for the duration of the time increment specified. The optimizer will consider changing speeds only at times which are multiples of this time increment.

```
SOA OPTION SELECTION

Default SOA options (in knots) are:   5 10 15 20 25
Do you wish to specify values different from these?
```

Figure 4-22

```
SOA OPTION SELECTION

Default SOA options (in knots) are:   5 10 15 20 25
Do you wish to specify values different from these?  y

Enter minimum SOA (knots):  5

Enter maximum SOA (knots):  30

Enter SOA increment (knots):  5
```

Figure 4-23

```
SOA OPTION SELECTION

Default SOA options (in knots) are:   5 10 15 20 25
Do you wish to specify values different from these?  y

Enter minimum SOA (knots):  5

Enter maximum SOA (knots):  30

Enter SOA increment (knots):  5

Current SOA options (in knots) are:   5 10 15 20 25 30
Are these values correct?  y
```

Figure 4-24

For the example shown in Figure 4-25, the default time increment of eight hours has been chosen. Thus, the optimizer will consider SOA changes with a frequency of three times a day.

With the specification of the time increment for SOA changes, the second phase of transit plan definition is complete.

4.4.6 Fuel Costs - The next portion of the transit plan definition process is concerned with the assessment of "fuel costs"; it begins with the screen image of Figure 4-26. The user is asked to specify the relative "costs" of the various SOA options with respect to one another and with respect to other criteria considered later in the elicitation process, namely, detection aversion and evasive action costs.

The fuel costs assessed here can reflect more than just the cost of fuel associated with each SOA option. They can indicate the user's unhappiness with each SOA option relative to the others (and relative to the other two criteria) for any reason whatsoever. For example, the user may like an SOA of 5 knots less than one of 10 knots because his ships do not respond as well to the helm in heavy seas at the slower speed.

Values specified for fuel cost (and for the other cost criteria, as well) must be in the range from 0 to 100, where 100 represents the greatest cost and 0 the least. Only whole-numbered values are permitted.

For a scenario in which fuel costs are relatively small compared with the cost of detection (discussed in Section 4.4.7), the user might assess fuel costs as shown

```
SOA OPTION SELECTION

Default SOA options (in knots) are:   5 10 15 20 25
Do you wish to specify values different from these?  y

Enter minimum SOA (knots):  5

Enter maximum SOA (knots):  30

Enter SOA increment (knots):  5

Current SOA options (in knots) are:   5 10 15 20 25 30
Are these values correct?  y

Default time increment for SOA changes is 8 hours.

Do you wish to specify a different value?  no
```

Figure 4-25

```
FUEL COST ASSESSMENT

Note:  Fuel cost must be specified for each SOA option.
       Cost values must be in the range from 0 to 100
       and must be consistent with values specified for
       detection aversion costs and evasive action costs.

Enter fuel cost for SOA option   5 knots:
```

Figure 4-26

in Figure 4-27. When the last of these values has been entered, the Aid asks the user to verify their correctness as shown in Figure 4-28. If the user is not satisfied with the values, the Aid will repeat the sequence of requests in Figure 4-27. Otherwise, the next step in transit plan definition begins, namely, detection aversion specification.

4.4.7 Detection Aversion Profile - Detection aversion, like fuel costs, must be assessed in relation to the entire set of cost criteria. Detection aversion is a measure of how unhappy the user would be if he were detected during his planned transit (and identified as a target of interest) by hostile surveillance forces. Like fuel costs, aversion to detection could be expressed simply as a single value on the scale from 0 to 100.

It may happen, however, that a user's aversion to detection varies as a function of his progress through his transit. In particular, the user may be more concerned with detection near the end of the transit than near the beginning. To accommodate situations such as this, the user is presented with a number of detection aversion functions, or profiles, when this stage of transit plan definition begins. These profiles appear in Figure 4-29.

Each detection aversion profile represents a possible variation of detection aversion as a function of distance (labeled as "distance fraction") along the track plan. Profile 1 indicates that avoiding detection is more critical near the point of departure than near the destination. Profile 2 represents the converse situation: avoiding detection is more critical near the destination than near the point of departure. Profile 3 implies that detection avoidance is equally important at all points of the transit; this is equivalent to expressing detection aversion as a single value, as discussed above. Profiles 4 and 5 indicate

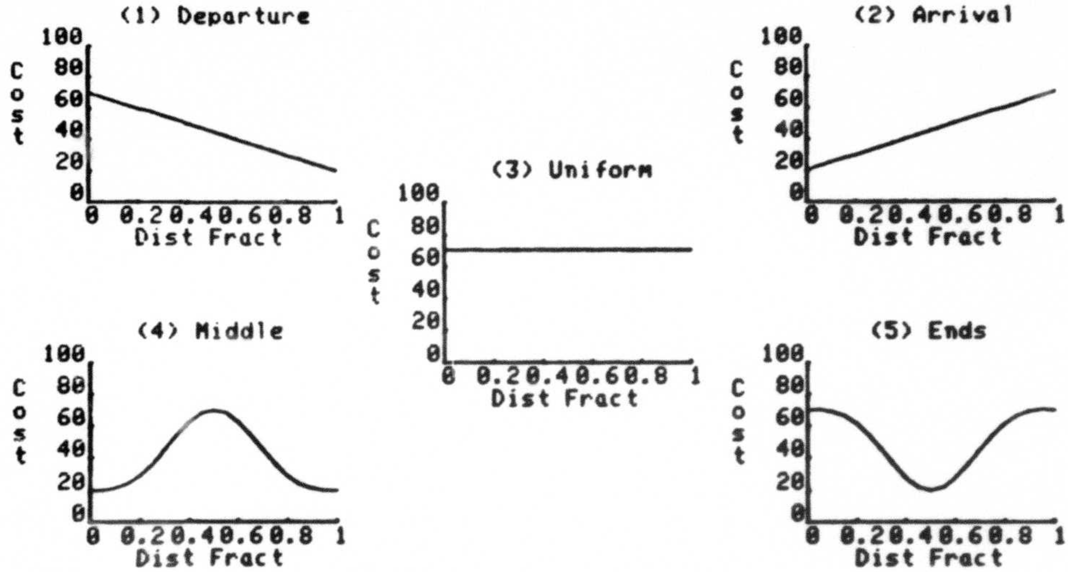
```
FUEL COST ASSESSMENT

Note:  Fuel cost must be specified for each SOA option.
       Cost values must be in the range from 0 to 100
       and must be consistent with values specified for
       detection aversion costs and evasive action costs.

Enter fuel cost for SOA option   5 knots:  7
Enter fuel cost for SOA option  10 knots:  6
Enter fuel cost for SOA option  15 knots:  5
Enter fuel cost for SOA option  20 knots:  5
Enter fuel cost for SOA option  25 knots:  6
Enter fuel cost for SOA option  30 knots:  7
```

Figure 4-27

```
Current fuel costs are:

SOA Option  Fuel Cost

     5          7
    10          6
    15          5
    20          5
    25          6
    30          7

Are these values correct?  y

Press RETURN to continue...
```

Figure 4-28

DETECTION AVERSION PROFILE SELECTION



Enter number of profile which best represents your
aversion to detection:

Figure 4-29

that the middle and the ends of the transit, respectively, are the most critical regions for avoiding detection. Other profiles could be provided, but these seem to cover the most frequently encountered situations.

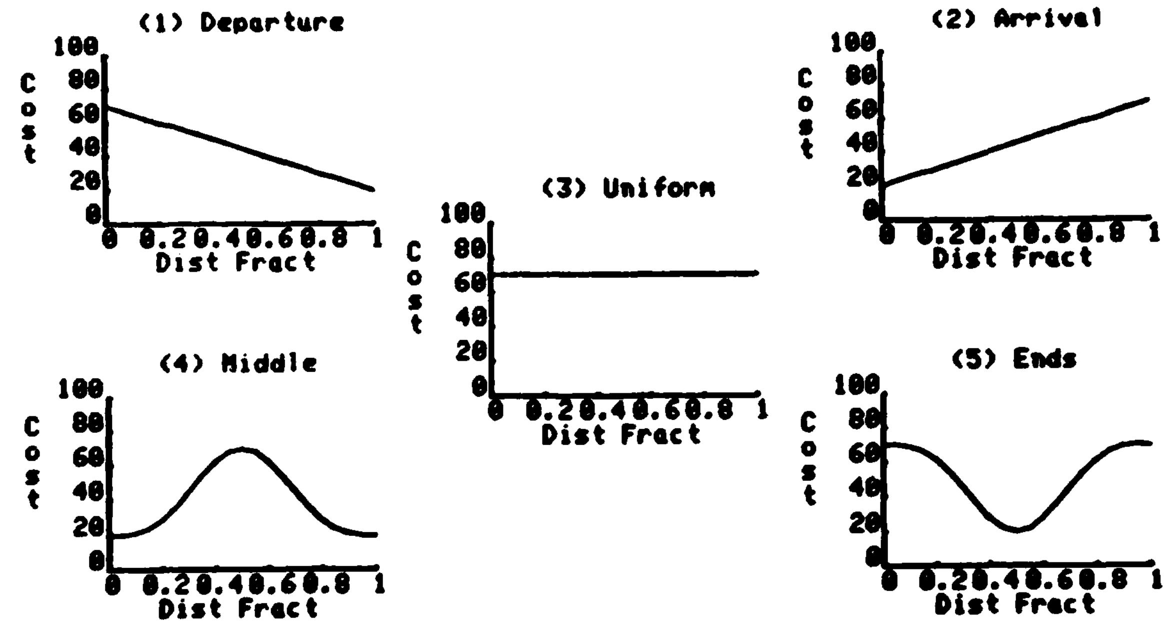
The user must select one profile which best represents his aversion to detection for the transit under consideration. The cost values associated with the profiles will undoubtedly not match those that the user would like, but the user will be given the opportunity to specify his own values once a profile has been selected. Therefore, in selecting a profile, the user should be concerned only with the shape of the function, not its values.

Figure 4-30 depicts the selection of profile 4; this causes the image of Figure 4-31 to appear. At this point the user is given the opportunity to specify cost values. If profile 3 had been chosen, the Aid would request just a single value.

The values must lie in the range from 0 to 100, where 100 represents the greatest aversion to detection. The minimum value must be less than or equal to the maximum value specified. Only whole-numbered values may be specified.

Once the user has specified the cost parameters for the type of profile he has selected, the Aid will display that profile, modified to reflect the parameter values assigned. The user is then asked to confirm that this profile reflects his true aversion to detection, as shown in Figure 4-32. If the user is unhappy with the resulting profile, he is given an opportunity either to specify different values or to select an entirely different profile. This completes the detection aversion assessment step of transit plan definition.

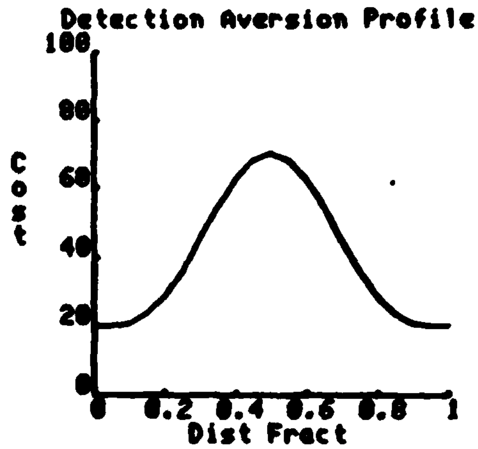
DETECTION AVERSION PROFILE SELECTION



Enter number of profile which best represents your
aversion to detection: 4

Figure 4-30

DETECTION AVERSION COST ASSESSMENT



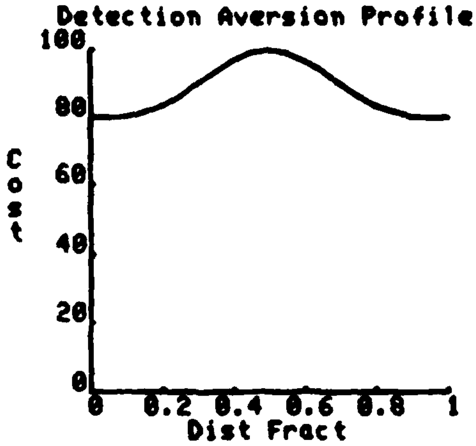
Note: Detection costs must be consistent with the values specified for fuel cost and evasive action costs.

Enter maximum detection cost (0-100): 100

Enter minimum detection cost (0-100): 80

Figure 4-31

DETECTION AVERSION COST REVIEW



Is this profile correct? y

Press RETURN to continue...

Figure 4-32

4.4.8 Evasive Action Costs - The final step in the transit plan definition sequence is the assessment of costs for the various evasive actions which may be employed to thwart detection. The set of possible evasive actions and a default cost for each comes from the host computer. (See Sections 4.6.2 and 4.7.2). Since changes in these are likely to be infrequent, the user can generally ignore this fact.

As this step begins, the Aid displays the image of Figure 4-33. The evasive action descriptors are those last received from the host, but the costs associated with them are the costs as last specified by the user (perhaps for an earlier transit plan). They may be default costs, of course, if the user has never made any changes.

```
EVASIVE ACTION COSTS

     Evasive Action                Cost

( 1) NORMAL OPERATIONS                0
( 2) EMCON                           20
( 3) RECONFIGURE (MERCHANT)           5
( 4) ZIG-ZAG                          5
( 5) EM SPOOF (MERCHANT)              5
( 6) DECOY (CHAFF)                    5
( 7) JAM                             10

( 8) None of the above

Enter number of item to be changed:
```

Figure 4-33

At this point the user is given an opportunity to change any cost or to leave them all unchanged. In Figure 4-34 the cost of EMCON has been selected for change. The value specified must be consistent with costs assessed for the other evasive actions and with the costs specified for fuel cost and detection aversion.

```
EVASIVE ACTION COSTS

     Evasive Action                 Cost

( 1) NORMAL OPERATIONS                 0
( 2) EMCON                            20
( 3) RECONFIGURE (MERCHANT)            5
( 4) ZIG-ZAG                           5
( 5) EM SPOOF (MERCHANT)               5
( 6) DECOY (CHAFF)                     5
( 7) JAM                              10

( 8) None of the above

Enter number of item to be changed:  2

Note:  Evasive action costs must be consistent with the
       values specified for fuel cost and detection cost.

Enter revised cost (0-100) for evasive action 2:  5
```

Figure 4-34

The values specified for evasive action costs must lie between 0 and 100, where 100 represents the greatest cost. Only whole-numbered values are permitted.

Once a value has been entered, the cost table is redisplayed with the corresponding entry changed as shown in Figure 4-35. Again the user is given an opportunity to change any cost, and the process may be repeated.

When the user finally selects "None of the above," as in Figure 4-36, the evasive action cost step terminates and the transit plan definition sequence is complete. Pressing RETURN at this point causes the title page of Figure 4-11 to appear, and the user is given an opportunity to select another activity. Note that having defined a new transit plan invalidates any results which may have been calculated previously and causes option 5 of the title page option list to become "Calculate results."

```
EVASIVE ACTION COSTS

     Evasive Action                      Cost

( 1) NORMAL OPERATIONS                      0
( 2) EMCON                                  5
( 3) RECONFIGURE (MERCHANT)                 5
( 4) ZIG-ZAG                                5
( 5) EM SPOOF (MERCHANT)                    5
( 6) DECOY (CHAFF)                          5
( 7) JAM                                   10

( 8) None of the above

Enter number of item to be changed:
```

Figure 4-35

```
EVASIVE ACTION COSTS

     Evasive Action                      Cost

( 1) NORMAL OPERATIONS                      0
( 2) EMCON                                  5
( 3) RECONFIGURE (MERCHANT)                 5
( 4) ZIG-ZAG                                5
( 5) EM SPOOF (MERCHANT)                    5
( 6) DECOY (CHAFF)                          5
( 7) JAM                                   10

( 8) None of the above

Enter number of item to be changed:  8
```

Figure 4-36

4.5 Transit Plan Review and Editing

If the user selects the "Review/edit transit plan" option from the title page option list, as shown in Figure 4-37, the Aid will give the user an opportunity to examine and optionally to change any of the parameter values originally assessed in the transit plan definition sequence described in Section 4.4. This option may be selected from any one of the three different title pages (Figures 4-10, 4-11, and 4-12).

When the review/edit option is selected, the user is presented with the option menu of Figure 4-38. With the exception of option 5, each of the options in this menu allows the user to examine and to alter a subset of the parameter values elicited during the transit plan definition sequence.

```
                Department of Defense
          Advanced Research Projects Agency
      (Information Processing Technology Office)

    SATELLITE SURVEILLANCE AVOIDANCE OPTIMIZATION AID

                    developed by
               Decisions & Designs, Inc.

OPTIONS:

(1)  Introduction
(2)  Define new transit plan
(3)  Review/edit transit plan
(4)  Review environmental parameters
(5)  Calculate  results
(6)  Stop execution

Enter number of option desired:  3
```

Figure 4-37

```
TRANSIT PLAN REVIEW/EDIT OPTIONS:

(1) Track Plan
(2) SOA Options & Fuel Costs
(3) Detection Aversion Profile
(4) Evasive Action Costs
(5) None of the above

Enter number of option desired:
```

Figure 4-38

Selecting option 5, as shown in Figure 4-39, will cause the title page to reappear. If before selecting option 5 one of the first four options is selected and one or more parameter values is changed, then any results which may have been calculated previously will be invalidated; this will force the title page to assume the form of Figure 4-11 in which the fifth option is "Calculate results."

```
TRANSIT PLAN REVIEW/EDIT OPTIONS:

(1) Track Plan
(2) SOA Options & Fuel Costs
(3) Detection Aversion Profile
(4) Evasive Action Costs
(5) None of the above

Enter number of option desired:  5
```

Figure 4-39

The parameters presented for review within each of the first four options should be largely self-evident. The track plan consists of departure and arrival times; point of departure, destination, and intermediate point latitudes and longitudes; and probability of prior tracking. In addition to SOA options and fuel costs, the second option includes the time increment for SOA changes. The third and fourth options are concerned with detection aversion and evasive action costs, respectively, as their names imply.

4.5.1 Track Plan - When the track plan option is selected, as shown in Figure 4-40, the image of Figure 4-41 appears on the screen. This table contains the current value of each of the indicated parameters, either as specified during the transit plan definition process or as modified by a previous excursion into the review/edit mode.

At this point the user is free to change any value. He may do so by specifying the number of the item to be changed and then entering a new value in response to the request which appears, as shown in Figure 4-42. The new-value requests are identical in form to those used in the transit plan definition sequence, including the requirement to confirm the correctness of each entry made. Refer to Sections 4.4.1, 4.4.2, and 4.4.3 for descriptions of entry syntax.

After each value change is made, the Aid will display the entire table of values, reflecting the change. When the user has finished modifying values in the table or if he wishes to make none at all, he must select the last option in the menu as shown in Figure 4-43. This will cause the review/edit menu of Figure 4-38 to reappear. At this point the user may select another category of parameters to examine or to change, or he may return to the option list of the title page by selecting option 5.

```
TRANSIT PLAN REVIEW/EDIT OPTIONS:

(1) Track Plan
(2) SOA Options & Fuel Costs
(3) Detection Aversion Profile
(4) Evasive Action Costs
(5) None of the above

Enter number of option desired:  1
```

Figure 4-40

```
TRACK PLAN CHARACTERISTICS

( 1) Departure time:                 0600 17 NOV 77
( 2) Arrival time:                   1600 26 NOV 77
( 3) Departure latitude:              36 53 59N
( 4) Departure longitude:            076 17 59W
( 5) Point  1 lat.tude:               30 00 00N
( 6) Point  1 longitude:             020 00 00W
( 7) Destination latitude:            35 56 59N
( 8) Destination longitude:          005 35 59W
( 9) Prior tracking probability:     0.05
(10) None of the above

Enter number of item to be changed:
```

Figure 4-41

```
TRACK PLAN CHARACTERISTICS

( 1) Departure time:                0600 17 NOV 77
( 2) Arrival time:                  1600 26 NOV 77
( 3) Departure latitude:             36 53 59N
( 4) Departure longitude:           076 17 59W
( 5) Point  1 latitude:              30 00 00N
( 6) Point  1 longitude:            020 00 00W
( 7) Destination latitude:           35 56 59N
( 8) Destination longitude:         005 35 59W
( 9) Prior tracking probability:    0.05
(10) None of the above

Enter number of item to be changed:  9

Enter probability of already being tracked
     at departure (0.00-1.00):  .1                              .1
Is this value correct?  y
```

Figure 4-42

```
TRACK PLAN CHARACTERISTICS

( 1) Departure time:                0600 17 NOV 77
( 2) Arrival time:                  1600 26 NOV 77
( 3) Departure latitude:             36 53 59N
( 4) Departure longitude:           076 17 59W
( 5) Point  1 latitude:              30 00 00N
( 6) Point  1 longitude:            020 00 00W
( 7) Destination latitude:           35 56 59N
( 8) Destination longitude:         005 35 59W
( 9) Prior tracking probability:    0.10
(10) None of the above

Enter number of item to be changed:  10
```

Figure 4-43

4.5.2 SOA Options and Fuel Costs - If the user selects option 2 from the review/edit menu, as shown in Figure 4-44, a table of current SOA options and fuel costs will be displayed in the format of Figure 4-45.

```
TRANSIT PLAN REVIEW/EDIT OPTIONS:

(1) Track Plan
(2) SOA Options & Fuel Costs
(3) Detection Aversion Profile
(4) Evasive Action Costs
(5) None of the above

Enter number of option desired:  2
```

Figure 4-44

```
SOA OPTIONS & FUEL COSTS

( 1) Minimum SOA (knots):                          5
( 2) Maximum SOA (knots):                         30
( 3) SOA increment (knots):                        5
( 4) Time increment for SOA changes (hrs):         8

     SOA Option  Fuel Cost

( 5)     5           7
( 6)    10           6
( 7)    15           5
( 8)    20           5
( 9)    25           6
(10)    30           7

(11) None of the above

Enter number of item to be changed:
```

Figure 4-45

The user may select any item to change by specifying its number in response to the "Enter number ..." query. He must then provide a new value in response to the request which subsequently appears, such as the one in Figure 4-46. Requests for new values are identical in form to those used in the transit plan definition sequence. Descriptions of the response syntax for these requests are provided in Sections 4.4.4, 4.4.5, and 4.4.6.

After each value change is made, the table of values will be redisplayed to reflect the change. If (and only if) the minimum SOA, the maximum SOA, or the SOA increment is changed, only a portion of the original table will reappear; fuel costs are excluded. Any change in the SOA options invalidates previously assessed fuel costs; they must therefore be reassessed. This situation is depicted in Figure 4-47, which would result from the value change shown in Figure 4-46. At this point changes to any values in the abbreviated table are still permissible. When the user finally selects "None of the above," the fuel cost assessment process will occur as shown in Figure 4-48. At the completion of this process, the entire table of SOA options and fuel costs will be displayed again as in Figure 4-49.

When the user wishes to make no further changes, he must select "None of the above" (from the full table display). This will cause the review/edit menu of Figure 4-38 to reappear. From that menu the user may select another set of parameters for review or change, or he may return to the title page option list by selecting option 5.

4.5.3 Detection Aversion Profile - If the user selects option 3 from the review/edit option list, as depicted in Figure 4-50, he will be presented with a plot of the current detection aversion profile and he will be given the opportunity to revise the minimum and maximum costs associated with

```
SOA OPTIONS & FUEL COSTS

( 1) Minimum SOA (knots):                          5
( 2) Maximum SOA (knots):                         30
( 3) SOA increment (knots):                        5
( 4) Time increment for SOA changes (hrs):         8

     SOA Option  Fuel Cost

( 5)     5          7
( 6)    10          6
( 7)    15          5
( 8)    20          5
( 9)    25          6
(10)    30          7

(11) None of the above

Enter number of item to be changed:  2

Enter maximum SOA (knots):  25
```

Figure 4-46

```
SOA OPTIONS & FUEL COSTS

( 1) Minimum SOA (knots):                          5
( 2) Maximum SOA (knots):                         25
( 3) SOA increment (knots):                        5
( 4) Time increment for SOA changes (hrs):         8
( 5) None of the above

New fuel costs will be requested when 'none' is selected.

Enter number of item to be changed:  5
```

Figure 4-47

```
Enter fuel cost for SOA option   5 knots:  7
Enter fuel cost for SOA option  10 knots:  6
Enter fuel cost for SOA option  15 knots:  5
Enter fuel cost for SOA option  20 knots:  6
Enter fuel cost for SOA option  25 knots:  7
```

Figure 4-48

```
SOA OPTIONS & FUEL COSTS

( 1) Minimum SOA (knots):                           5
( 2) Maximum SOA (knots):                          25
( 3) SOA increment (knots):                         5
( 4) Time increment for SOA changes (hrs):          8

    SOA Option  Fuel Cost

( 5)     5          7
( 6)    10          6
( 7)    15          5
( 8)    20          6
( 9)    25          7

(10) None of the above

Enter number of item to be changed:  10
```

Figure 4-49

```
TRANSIT PLAN REVIEW/EDIT OPTIONS:

(1) Track Plan
(2) SOA Options & Fuel Costs
(3) Detection Aversion Profile
(4) Evasive Action Costs
(5) None of the above

Enter number of option desired:  3
```

Figure 4-50

it or to select an entirely different profile. This situation is illustrated in Figure 4-51.

Selecting either of the modification options causes the Aid to behave in the same manner as it does during the transit plan definition process, as described in Section 4.4.7. Selecting the cost revision option results in a dialogue similar to that depicted by Figure 4-31; selecting the new profile option results in the dialogue of Figures 4-30, 4-31, and 4-32.

If the user elects to revise only the costs associated with the current profile, the image of Figure 4-51 will reappear once the new values have been specified. In this case, selecting "None of the above" as in Figure 4-52 will cause the review/edit menu of Figure 4-38 to reappear. If the user elects to choose an entirely different detection aversion profile, the review/edit menu will reappear after the confirmation step of Figure 4-32. At this point the user may select another category of parameters for review or modification, or he may return to the title page option list by selecting option 5.

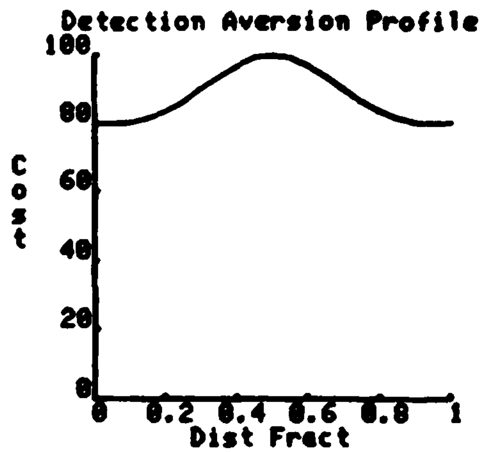
4.5.4 Evasive Action Costs - To review or edit evasive action costs, the user must select option 4 from the review/edit menu, as shown in Figure 4-53. When this option is picked, the table of values shown in Figure 4-54 will appear.

The dialogue for changing values in this table is identical to that encountered in the transit plan definition process described in Section 4.4.8.

When the user selects "None of the above" as in Figure 4-55, the review/edit menu of Figure 4-38 will be redisplayed. The user may then choose another set of

DETECTION AVERSION

(1) Entire aversion profile
(2) Min and max costs only
(3) None of the above

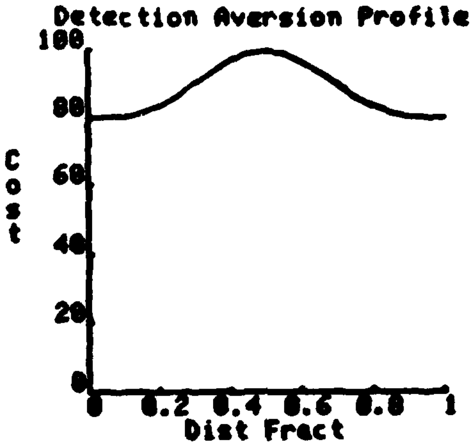


Enter number of item to be changed:

Figure 4-51

DETECTION AVERSION

(1) Entire aversion profile
(2) Min and max costs only
(3) None of the above



Enter number of item to be changed: 3

Figure 4-52

```
TRANSIT PLAN REVIEW/EDIT OPTIONS:

(1) Track Plan
(2) SOA Options & Fuel Costs
(3) Detection Aversion Profile
(4) Evasive Action Costs
(5) None of the above

Enter number of option desired:  4
```

Figure 4-53

```
EVASIVE ACTION COSTS

     Evasive Action                  Cost

( 1) NORMAL OPERATIONS                  0
( 2) EMCON                              5
( 3) RECONFIGURE (MERCHANT)             5
( 4) ZIG-ZAG                            5
( 5) EM SPOOF (MERCHANT)                5
( 6) DECOY (CHAFF)                      5
( 7) JAM                               10

( 8) None of the above

Enter number of item to be changed:
```

Figure 4-54

```
EVASIVE ACTION COSTS

     Evasive Action              Cost

( 1) NORMAL OPERATIONS              0
( 2) EMCON                          5
( 3) RECONFIGURE (MERCHANT)         5
( 4) ZIG-ZAG                        5
( 5) EM SPOOF (MERCHANT)            5
( 6) DECOY (CHAFF)                  5
( 7) JAM                           10

( 8) None of the above

Enter number of item to be changed:  8

Press RETURN to continue...
```

Figure 4-55

parameters to examine or to edit, or he may return to the option menu of the title page by selecting option 5.

4.6 Environmental Parameter Review

The satellite intercept calculations and the optimization process depend very much upon the context, or environment, in which a transit will occur. In particular, these calculations depend upon the numbers and types of extant surveillance satellites, the weather along the transit route, and the efficacies of various evasive actions which may be employed to thwart detection.

For the most part the impacts of these environmental factors vary with the time and the location of a transit. As a result, a new set of parameter values is required whenever the transit plan changes.

If the user selects the "Review environmental parameters" option from the title page option list, as shown in Figure

4-56, he will be given an opportunity to examine the specific environmental parameters associated with the currently defined transit plan.

The environmental parameters fall into four categories:

- o Satellite detection probabilities
- o Satellite-in-operation probabilities
- o Satellite descriptions
- o Weather probabilities

These categories are discussed in the following subsections: 4.6.3, 4.6.4, 4.6.5, and 4.6.6. Their involvement in the satellite intercept calculations and the optimization process is described in Sections 2.0 and 3.0.

```
                    Department of Defense
               Advanced Research Projects Agency
          (Information Processing Technology Office)

     SATELLITE SURVEILLANCE AVOIDANCE OPTIMIZATION AID

                        developed by
                  Decisions & Designs, Inc.
OPTIONS:

(1)  Introduction
(2)  Define new transit plan
(3)  Review/edit transit plan
(4)  Review environmental parameters
(5)  Calculate  results
(6)  Stop execution

Enter number of option desired:  4
```

Figure 4-56

4.6.1 Host Computer Involvement - The environmental parameters characterize information about which the typical user will have no knowledge. Therefore, he cannot be expected to provide this information to the Aid; other independent sources must be consulted to obtain the needed parameter values. The mechanism used to extract these assessments from the diverse sources or experts is to place the burden on the host computer. In general, the host can contain the procedures required to query processes or data bases established by other users or resident on other computers in a network environment. Thus, weather data can be obtained from FNWC, and satellite characteristics can be extracted automatically from intelligence data bases in a manner which isolates the user from the potential complexity of such retrieval processes.

In the current implementation of the Aid, the host computer software does not actually access the specialized processes or data bases required in either an actual or a simulated operational environment. However, by employing this design philosophy and providing the appropriate "hooks," conversion to a near-operational environment is simplified. Therefore, processes to simulate the actions which would be undertaken by the eventual host software have been implemented for the current version of the Aid.

In light of the responsibility assigned to the host computer to provide environmental parameter data, the user will encounter situations in which connection of the 4051 terminal to the host is required. If the title page menu is of the form shown in either Figure 4-10 or Figure 4-12; that is, if results for the currently defined transit

have previously been calculated, then the environmental parameters will be available for immediate review, and connection to the host is not required. On the other hand, if the title page menu is as shown in Figure 4-11 (or Figure 4-56), indicating that results are yet to be calculated, then the environmental parameter values must be made consistent with the transit plan; and the user may be asked to establish communication between the terminal and the host. The form of this request is illustrated in Figure 4-57. The specifics of this process will differ slightly for different hosts, of course. This step will not be required if communication was previously established for environmental parameter review or for result calculation (discussed in Section 4.7.1).

```
Communication with host is required for data transfer.

Establish Tip Connection by dialing phone and
  inserting phone in coupler.

Then press 'RETURN TO BASIC' key (function key 05).

HOST-LOGIN PROCESS (for ARPAnet Host)

@1 116
Trying...
 Open


 ISI-SYSTEM-E, TOPS-20 Monitor 1010(1221)-1
 System shutdown scheduled for 13-Nov-78 22:00:00,
 Up again at 14-Nov-78 05:00:00
@LOG
(USER) DDI-SURUAU
(PASSWORD)
(ACCOUNT)
 Job 26 on TTY171 13-Nov-78 07:06
@SURUAU
!hlo
```

Figure 4-57

4.6.2 Environmental Parameter Validation - As indicated in Section 4.6.1 above, when a new transit plan has been defined and results have not yet been calculated, the environmental parameter values must be updated to be consistent with the transit plan. Under certain (but not all) conditions, changes to a transit plan may indicate the need for an update as well.

As a rule, satellite detection probabilities (and evasive actions, on which the satellite detection probabilities depend), satellite-in-operation probabilities, and satellite descriptions (or characteristics) are not very volatile. These parameters probably change only infrequently--no more often than daily. Weather probabilities, on the other hand, may change more frequently. On this basis the Aid makes the assumption that all environmental parameters need updating no more frequently than the weather probabilities. This assumption helps to minimize the amount of data traffic between the terminal and the host, a design criterion. Therefore, environmental parameter values are updated only when the weather probabilities need updating.

There are two conditions--changes in the transit plan--for which weather probability updates are required, namely, a change in transit time or a change in transit location. Thus, if the departure time, the arrival time, or the track plan (the route) changes, the weather probabilities will require an update. These conditions obviously include the situation in which an entirely new transit plan has been defined.

If the need for environmental parameter updates is indicated, the Aid will conduct an environmental parameter "validation" sequence. In this validation sequence the host sends the terminal a "time stamp" for each set of parameters (with the exception of the weather probabilities). The terminal compares the time stamp sent by the host with the time stamp that it has for each set of parameters. If the time stamps match, the parameter values stored on the terminal tape cartridge are known to match the parameter values held by the host; in this case, no data need be transferred. If the time stamps do not match, the host values are sent to

the terminal and are marked with the new (host) time stamp. This validation mechanism helps to minimize the amount of data traffic between host and terminal.

When the environmental parameter validation sequence is in progress, a display image like that of Figure 4-58 is produced so that the user can follow the progress of the sequence. Note that for the example shown the only parameters other than weather probabilities which required an update were the satellite-in-operation probabilities.

The only action required of the user during the validation sequence is to press the RETURN key when asked to do so.

```
ENVIRONMENTAL PARAMETER VALIDATION

     The environmental parameter values stored on this tape
cartridge must be validated to insure that they correspond
to the most current values available to the host.
     If discrepencies occur, updated values will be
requested from the host.

Evasive action validation...
     No update required.

Satellite detection probability validation...
     No update required.

Satellite-in-operation probability validation...
     Update required--data transfer in progress...
     Data transfer complete.

Satellite description validation...
     No update required.

Updated weather probabilities are always required when a
new or revised transit plan has been specified.
     Track plan transfer (to host) in progress...
     Track plan transfer complete.
     Weather probability transfer in progress...
     Weather probability transfer complete.

All environmental parameter updates are complete--
     press RETURN to continue...
```

Figure 4-58

Once the environmental parameter validation sequence is complete (or if validation is not necessary), the user will be presented with a menu of environmental parameter review options, as shown in Figure 4-59. Selecting option 5, "None of the above," from this menu will cause the title page to reappear.

4.6.3 Satellite Detection Probabilities - If the user selects option 1 from the environmental parameter review menu, as shown in Figure 4-60, the table of satellite detection probabilities shown in Figure 4-61 will be displayed. These probabilities are used in the optimization process described in Section 3.0.

As the table of Figure 4-61 indicates, the probability of detection by a satellite is a function of three variables: (1) the type of the satellite (optical, infrared, radar, COMINT, or ELINT in this example), (2) the nature of the evasive action which is employed to thwart the satellite, and (3) whether or not the task force or ship is already being tracked.

The type of the satellite is significant because the various sensors have different sensitivities or resolutions. The evasive action is important because certain actions are effective against one type of satellite but not against another. For example, EMCOM would reduce the probability of detection by a COMINT or an ELINT satellite but would have no effect for an optical satellite. Finally, tracking condition is important because the information gathered by a particular satellite is more likely to be examined closely if the surveillance forces are already tracking the task force.

```
ENVIRONMENTAL PARAMETER REVIEW OPTIONS

(1) Satellite Detection Probabilities
(2) Satellite-in-Operation Probabilities
(3) Satellite Descriptions
(4) Weather Probabilities
(5) None of the above

Enter number of option desired:
```

Figure 4-59

```
ENVIRONMENTAL PARAMETER REVIEW OPTIONS

(1) Satellite Detection Probabilities
(2) Satellite-in-Operation Probabilities
(3) Satellite Descriptions
(4) Weather Probabilities
(5) None of the above

Enter number of option desired:  1
```

Figure 4-60

SATELLITE DETECTION PROBABILITIES

Each table entry represents the probability of detection given evasive action, type of satellite, and tracking condition.

Evasive Action
(1) = Tracking
(2) = Not tracking

Evasive Action		Satellite Type O	I	R	C	E
NORMAL OPERATIONS	(1)	0.40	0.55	0.70	0.80	0.90
	(2)	0.10	0.15	0.50	0.30	0.40
EMCON	(1)	0.40	0.55	0.70	0.05	0.10
	(2)	0.10	0.15	0.50	0.01	0.05
RECONFIGURE (MERCHANT)	(1)	0.40	0.50	0.70	0.80	0.90
	(2)	0.10	0.10	0.50	0.30	0.40
ZIG-ZAG	(1)	0.40	0.55	0.70	0.80	0.90
	(2)	0.10	0.15	0.50	0.30	0.40
EM SPOOF (MERCHANT)	(1)	0.40	0.55	0.70	0.40	0.50
	(2)	0.10	0.15	0.50	0.10	0.20
DECOY (CHAFF)	(1)	0.40	0.60	0.80	0.80	0.90
	(2)	0.10	0.20	0.50	0.30	0.40
JAM	(1)	0.40	0.55	0.10	0.10	0.10
	(2)	0.10	0.15	0.01	0.01	0.05

Press RETURN to continue...

Figure 4-61

The ultimate probability of detection depends upon two other factors as well: weather and the operational status of each satellite. These factors are accounted for by the satellite-in-operation probabilities and the weather probabilities discussed in Sections 4.6.4 and 4.6.6, respectively. The satellite detection probabilities in the table of Figure 4-61 are assessed under the assumptions that the given satellite is turned on and is operating and that the weather conditions will permit detection.

When the user presses the RETURN key as requested in Figure 4-61, the environmental parameter review menu will reappear, and the user will have the opportunity to examine another set of parameters.

4.6.4 Satellite-In-Operation Probabilities - If the user selects option 2 from the environmental parameter review menu, as shown in Figure 4-62, the table of satellite-in-operation probabilities shown in Figure 4-63 will be displayed. These probabilities, along with the satellite detection probabilities and the weather probabilities described in Sections 4.6.3 and 4.6.6, respectively, are used in the optimization process described in Section 3.0.

As the table of Figure 4-63 shows, the probability that a satellite will be turned on is assumed to be a function of two variables: (1) the type of the satellite, and (2) whether or not the task force is already being tracked.

The type of satellite influences the likelihood of its being turned on because the various satellites have different power "budgets." Each sensor has a particular rate of power consumption; as a rule, active sensors consume power at a faster rate than passive sensors. Given a finite supply of power, the amount of time that a satellite

ENVIRONMENTAL PARAMETER REVIEW OPTIONS

(1) Satellite Detection Probabilities
(2) Satellite-in-Operation Probabilities
(3) Satellite Descriptions
(4) Weather Probabilities
(5) None of the above

Enter number of option desired: 2

Figure 4-62

SATELLITE-IN-OPERATION PROBABILITIES

Each table entry represents the probability that a satellite is turned on, given type of satellite and tracking condition.

Satellite Type

	O	I	R	C	E
Tracking	0.80	0.80	0.50	0.90	0.90
Not tracking	0.01	0.01	0.01	0.50	0.50

Press RETURN to continue...

Figure 4-63

is operating must be controlled to budget the power supply over time.

For this same reason tracking condition is important. The expenditure of power to operate a sensor can be more easily justified if the task force is already being tracked than if a chance "hit" is being sought.

When the user presses the RETURN key as requested in Figure 4-63, the environmental parameter review menu will be displayed again.

4.6.5 Satellite Descriptions - Selecting option 3 from the environmental parameter review menu, as shown in Figure 4-64, causes a table of satellite characteristics to be displayed. An example of this table appears in Figure 4-65. The primary purpose of the table is to provide the user with a key to the satellite type codes which are used in other environmental parameter tables and in several result displays (Section 4.8). In addition to providing a simple definition of each type code (e.g., "O" represents "OPTICAL"), the table contains a brief description of the satellite sensor and indicates the nominal width of its footprint.

When the user presses the RETURN key as requested in Figure 4-65, the environmental parameter review menu appears once again, and the user may select another set of parameters for review.

4.6.6 Weather Probabilities - If the user selects option 4 from the environmental parameter review menu, as shown in Figure 4-66, the table of weather probabilities shown in Figure 4-67 will be displayed. These probabilities are used by the optimization process in conjunction with the satellite detection probabilities (Section 4.6.3) and the satellite-in-operation probabilities (Section 4.6.4) to

```
ENVIRONMENTAL PARAMETER REVIEW OPTIONS

(1) Satellite Detection Probabilities
(2) Satellite-in-Operation Probabilities
(3) Satellite Descriptions
(4) Weather Probabilities
(5) None of the above

Enter number of option desired:  3
```

Figure 4-64

```
SATELLITE DESCRIPTIONS

Type
Code   Description

 O     OPTICAL  - PASSIVE MONITOR, PASSIVE LOCATION       ; SWATH=245 N
 I     INFRARED - PASSIVE MONITOR, PASSIVE LOC, 8-12 MICR; SWATH=185 N
 R     RADAR    - VAR PULSE RATE XMTR, SYNTH APER ANT     ; SWATH= 55 N
 C     COMINT   - PASSIVE SIGNAL MONITOR, DF AT UHF & VHF; SWATH=480 N
 E     ELINT    - MICROWAVE MONITOR, PASSIVE RADIOMETRY  ; SWATH=540 N

Press RETURN to continue...
```

Figure 4-65

```
ENVIRONMENTAL PARAMETER REVIEW OPTIONS

(1) Satellite Detection Probabilities
(2) Satellite-in-Operation Probabilities
(3) Satellite Descriptions
(4) Weather Probabilities
(5) None of the above

Enter number of option desired:  4
```

Figure 4-66

WEATHER PROBABILITIES

Each table entry represents the probability that the weather will permit detection by a satellite, given type of satellite and day since departure.

Sat Type	Day 1	2	3	4	5	6	7	8	9
O	0.36	0.37	0.37	0.38	0.38	0.39	0.39	0.39	0.40
I	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
R	0.68	0.68	0.69	0.69	0.69	0.69	0.70	0.70	0.70
C	0.46	0.46	0.47	0.48	0.48	0.49	0.49	0.50	0.50
E	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98

Time & date probabilities were forecast: 1430 16 NOV 77

Press RETURN to continue...

Figure 4-67

determine the ultimate likelihood of detection for each possible satellite intercept. The specifics of this are discussed in Section 3.0.

Each entry in the table of Figure 4-67 represents the probability that the weather on a given day of the transit will permit detection by a particular satellite, assuming that the satellite is in operation.

The details of assessing weather probabilities for the ultimate operational Aid have not yet been determined. However, one can assume that planning a transit just prior to departure will permit fairly reliable weather forecast information to influence the assessment process. Planning a transit more than a day or two in advance of departure may imply that only historical trend data can be used. For example, from meteorological data recorded over the past thirty or forty years, one might infer that during a given week in December a particular area of the North Atlantic could expect 65 percent cloud cover, winds ranging from 15 to 20 knots, etc.

The current weather probability generation process attempts to simulate this state of affairs in the following manner. A set of seasonal weather probabilities for each of several major geographic areas has been assessed and is used to represent the probabilities which might be generated from historical weather data. When the weather probabilities for a given transit are to be generated, these seasonal probabilities are perturbed in a random way to simulate what might be more accurate weather information available about the geographic region of the transit at the time the transit is being planned. For each day in the future from the time of planning, weather forecast information is assumed less certain and the weather probabilities are made to converge asymptotically to the seasonal values.

Thus, transits planned just prior to departure will see weather probabilities which may be much different from the "steady state" values for the first day or two, whereas transits planned several days prior to departure will see weather probabilities which don't differ appreciably from the seasonal values.

When the user presses the RETURN key as requested in Figure 4-67, the environmental parameter review menu is displayed again and the user can examine another set of parameters, or he can return to the title page by selecting option 5, as shown in Figure 4-68.

```
ENVIRONMENTAL PARAMETER REVIEW OPTIONS

(1) Satellite Detection Probabilities
(2) Satellite-in-Operation Probabilities
(3) Satellite Descriptions
(4) Weather Probabilities
(5) None of the above

Enter number of option desired:  5
```

Figure 4-68

4.7 Result Calculation

Whenever the user has defined a new transit plan or has modified any parameter values of an existing transit plan, result calculation will be required. Consequently, the title page option menu will assume the form of Figure 4-11 in which option 5 is "Calculate results." Selecting this option, as shown in Figure 4-69, will cause the Aid to begin a series of steps leading to the calculation of results and ultimately to their display.

```
                  Department of Defense
            Advanced Research Projects Agency
     (Information Processing Technology Office)

   SATELLITE SURVEILLANCE AVOIDANCE OPTIMIZATION AID

                      developed by
                 Decisions & Designs, Inc.

OPTIONS:

(1)  Introduction
(2)  Define new transit plan
(3)  Review/edit transit plan
(4)  Review environmental parameters
(5)  Calculate  results
(6)  Stop execution

Enter number of option desired:  5
```

Figure 4-69

The steps of the result calculation sequence include the following:

- o Establish communication with the host computer, which is responsible for the actual result calculations.
- o Validate environmental parameters, if required.
- o Transfer transit plan parameter values to the host.
- o Validate transit plan parameters.
- o Calculate potential satellite intercepts with the planned ship route.

- o Calculate the optimal SOA profile for the transit.

- o Transfer results from the host to the terminal.

Each of these steps is described in Sections 4.7.1 through 4.7.7 below.

At the completion of the result calculation sequence, the Aid automatically presents the user with a result display menu. The options it contains are described in Section 4.8.

4.7.1 <u>Host Computer Involvement</u> - Since the host computer is responsible for carrying out the actual result calculations (see Section 3.0), the terminal must communicate a parametric description of the planned transit to the host; the host in turn must reply with a parametric description of the results. To this end, a communication link must be established between the two systems. If communication was previously established for environmental parameter review (Section 4.6.1) or for an earlier result calculation, this step need not be repeated.

Assuming that communication between the terminal and the host has not yet been established, the process outlined in Figure 4-70 will occur. Slight variations of this process will be required for different hosts, of course.

```
Communication with host is required for data transfer.

Establish Tip Connection by dialing phone and
  inserting phone in coupler.

Then press 'RETURN TO BASIC' key (function key 05).

HOST-LOGIN PROCESS (for ARPAnet Host)

@1 116
Trying...
 Open


 ISI-SYSTEM-E, TOPS-20 Monitor 1018(1221)-1
 System shutdown scheduled for 13-Nov-78 22:00:00,
 Up again at 14-Nov-78 05:00:00
@LOG
(USER) DOI-SURVAU
(PASSWORD)
(ACCOUNT)
 Job 26 on TTY171 13-Nov-78 07:06
@SURVAU
Ihlo
```

Figure 4-70

4.7.2 Environmental Parameter Validation - Once communication between the terminal and the host has been established, the Aid will address the validation of environmental parameters. This validation process is described in detail in Section 4.6.2. If no change in transit time or transit location has been made since the last validation, then this step will be skipped. This situation can arise in either of two ways: (1) the validation process has already been conducted as part of reviewing the environmental parameters (Section 4.6), or (2) the transit plan has been modified but neither transit time nor transit location was changed.

If environmental parameter validation is required, a display image like that of Figure 4-71 appears so that the user can monitor the progress of the validation process.

At the completion of the validation process the user must press the RETURN key to advance to the next step of the result calculation sequence.

4.7.3 Transfer of Transit Plan Parameters To Host Computer - Once communication between the terminal and the host has been established and environmental parameter validation is complete, the Aid will transfer a parametric description of the transit plan to the host. This description normally consists of all the parameter values elicited during the transit plan definition sequence described in Section 4.4. However, if the entire set of transit plan parameters was previously sent to the host and only a few parameter values have been changed, then only those sets of parameters which contain the changed values will be retransmitted.

ENVIRONMENTAL PARAMETER VALIDATION

The environmental parameter values stored on this tape cartridge must be validated to insure that they correspond to the most current values available to the host.
If discrepencies occur, updated values will be requested from the host.

Evasive action validation...
No update required.

Satellite detection probability validation...
No update required.

Satellite-in-operation probability validation...
Update required--data transfer in progress...
Data transfer complete.

Satellite description validation...
No update required.

Updated weather probabilities are always required when a new or revised transit plan has been specified.
Track plan transfer (to host) in progress...
Track plan transfer complete.
Weather probability transfer in progress...
Weather probability transfer complete.

All environmental parameter updates are complete--
press RETURN to continue...

Figure 4-71

Assume that the user has defined a new transit. Then all of the transit plan parameters must be transmitted to the host. These parameters are grouped (as described in Section 4.5) into the following categories:

- o Track plan
- o SOA options and fuel costs
- o Detection aversion profile
- o Evasive action costs

Since environmental parameter validation is required whenever transit time or transit location is changed, the track plan parameters will be transferred to the host during the environmental parameter validation process, as shown in Figure 4-71. Thus, during the transit plan transfer step only the other three categories of parameters need be sent to the host. This fact is conveyed to the user through the screen image of Figure 4-72, which appears on the display as the parameters are being transmitted.

On the other hand, if only a small number of parameter values have been changed, just the affected sets of parameters will be transferred. (This is true only if terminal-to-host communication has not been terminated and reestablished in the interim). For example, suppose that only the probability of prior tracking has been changed, as shown in Figure 4-73. Then only the track plan will have to be transmitted to the host. Since none of the time or location parameters has been changed, environmental parameter validation will not be required and the track plan will not have been transferred to the host prior to this step. The transit plan transfer screen image will then appear as shown in Figure 4-74.

```
RESULT CALCULATION

The host is responsible for result calculation.  Before
it can proceed, it must be sent the new or revised
transit plan parameters.

SOA option & fuel cost transfer in progress...
Transfer complete.

Detection aversion profile transfer in progress...
Transfer complete.

Evasive action cost transfer in progress...
Transfer complete.

Press RETURN to continue...
```

Figure 4-72

```
TRACK PLAN CHARACTERISTICS

( 1) Departure time:              0600 17 NOV 77
( 2) Arrival time:                1600 26 NOV 77
( 3) Departure latitude:           36 53 59N
( 4) Departure longitude:         076 17 59W
( 5) Point  1 latitude:            30 00 00N
( 6) Point  1 longitude:          020 00 00W
( 7) Destination latitude:         35 56 59N
( 8) Destination longitude:       005 35 59W
( 9) Prior tracking probability:  0.10
(10) None of the above

Enter number of item to be changed:  9

Enter probability of already being tracked
     at departure (0.00-1.00):  .65                          .65
Is this value correct?  y
```

Figure 4-73

RESULT CALCULATION

The host is responsible for result calculation. Before it can proceed, it must be sent the new or revised transit plan parameters.

Track plan transfer in progress...
Transfer complete.

Press RETURN to continue...

Figure 4-74

When transit plan transfer is complete and the user presses the RETURN key, the next step in the result calculation sequence, namely transit plan validation, will begin.

4.7.4 Transit Plan Parameter Validation - After the transit plan parameter values have been transferred to the host, the host will conduct a consistency check on certain key elements. For example, the length of the journey is checked against the maximum SOA to ensure that the transit can be completed in the time allotted. During this validation process, the screen will contain the image of Figure 4-75.

If errors are found, the user must correct them before attempting to calculate results again. The host will provide a message describing the nature of the error, and the terminal will display the title page so that the user can select an option for error correction (probably "Review/edit transit plan").

Assuming that transit plan validation is successful, the next step, potential intercept calculation, will begin.

```
RESULT CALCULATION

Transit plan parameter validation (by host) in progress...
Validation complete.
```

Figure 4-75

4.7.5 <u>Potential Intercept Calculation</u> - When transit plan parameter validation is complete, the host will normally begin a potential intercept calculation process to determine all regions along the transit route which will be subject to possible satellite surveillance during the time span of the transit. This process is described in detail in Section 2.0. Like the weather probabilities (Sections 4.6.2 and 4.6.6), the potential intercepts are dependent only upon the time and the location of the transit. Thus, if result calculation is being undertaken because parameters other than transit time or location have been changed, then the potential intercept calculation step will be skipped (assuming that terminal-to-host communication has not been terminated and reestablished in the interim).

If a new transit plan has been defined or if the time or the location of the transit has been changed, then the potential intercept calculation occurs and the screen image of Figure 4-76 appears, followed by that of Figure 4-77.

```
RESULT CALCULATION

Transit plan parameter validation (by host) in progress...
Validation complete.

Potential intercept calculation in progress...
```

Figure 4-76

```
RESULT CALCULATION

Transit plan parameter validation (by host) in progress...
Validation complete.

Potential intercept calculation in progress...
Potential intercept calculation complete.
```

Figure 4-77

On the other hand, if neither the time nor the location of the transit has been changed, the previously calculated potential intercepts will still be valid and this step will be skipped. In this case, the screen image of Figure 4-78 will appear.

Following this step comes the optimization step.

4.7.6 <u>Optimization Process</u> - Once the transit plan parameters have been validated and the potential intercepts have been calculated, the optimization process to calculate the optimal SOA profile begins. This process is described in detail in Section 3.0. As optimization begins, the user is presented with a display image like that of either Figure 4-79 or Figure 4-80, depending upon whether potential intercepts had to be calculated or not.

At the conclusion of the optimization process, the user is informed that the next step, result transfer, is about to begin (Figure 4-81 or 4-82).

4.7.7 <u>Transfer of Results to Terminal</u> - When the optimization process is finished, the host transfers the results of its calculations to the terminal to be saved on the program tape cartridge for later display. During the

RESULT CALCULATION

Transit plan parameter validation (by host) in progress...
Validation complete.

Potential intercepts previously calculated.

Figure 4-78

RESULT CALCULATION

Transit plan parameter validation (by host) in progress...
Validation complete.

Potential intercept calculation in progress...
Potential intercept calculation complete.

Optimization in progress...

Figure 4-79

RESULT CALCULATION

Transit plan parameter validation (by host) in progress...
Validation complete.

Potential intercepts previously calculated.

Optimization in progress...

Figure 4-80

RESULT CALCULATION

Transit plan parameter validation (by host) in progress...
Validation complete.

Potential intercept calculation in progress...
Potential intercept calculation complete.

Optimization in progress...
Optimization complete--result transfer to begin.

Figure 4-81

RESULT CALCULATION

Transit plan parameter validation (by host) in progress...
Validation complete.

Potential intercepts previously calculated.

Optimization in progress...
Optimization complete--result transfer to begin.

Figure 4-82

transfer process, the user is presented with a screen image like that of Figure 4-83 so that he can monitor the progress of the transfer.

Under certain circumstances not all result items will have to be transferred, since they will not have changed from the previous result calculation. The specific sets of results which must be sent to the terminal are indicated in Figure 4-84 as a function of the transit plan parameters which may be changed. As an example, Figure 4-85 illustrates the transfers which would occur if only the probability of prior tracking were changed.

```
RESULT CALCULATION

Transit plan parameter validation (by host) in progress...
Validation complete.

Potential intercept calculation in progress...
Potential intercept calculation complete.

Optimization in progress...
Optimization complete--result transfer to begin.

Basic result parameter transfer in progress...
Transfer complete.

Potential intercept transfer in progress...
Transfer complete.

SOA profile transfer in progress...
Transfer complete.

Actual intercept transfer in progress...
Transfer complete.

Track plot transfer in progress...
Transfer complete.

Result calculation & transfer is complete.
Press RETURN to continue...
```

Figure 4-83

Affected Results

Changed Transit Plan Parameter

		BASIC RESULT PARAMETERS*	POTENTIAL INTERCEPTS	SOA PROFILE	ACTUAL INTERCEPTS	TRACK PLOT**
Track Plan	DEP. OR ARRIVAL TIME	X	X	X	X	
	TRACK COORDINATES	X	X	X	X	X
	PRIOR PROBABILITY			X	X	
SOA Options & Fuel Costs	SOA OPTIONS	X		X	X	
	FUEL COSTS OR TIME INCR			X	X	
	DETECTION AVERSION PROFILE			X	X	
	EVASIVE ACTION COSTS			X	X	

*Includes parameters to describe minimum–maximum SOA parallelogram on intercept avoidance profile.

**Includes coordinates for plotting image of ship route.

Figure 4-84

RESULT VALUES AFFECTED BY TRANSIT PLAN PARAMETER CHANGES

```
RESULT CALCULATION

Transit plan parameter validation (by host) in progress...
Validation complete.

Potential intercepts previously calculated.

Optimization in progress...
Optimization complete--result transfer to begin.

SOA profile transfer in progress...
Transfer complete.

Actual intercept transfer in progress...
Transfer complete.

Result calculation & transfer is complete.
Press RETURN to continue...
```

Figure 4-85

When all result transfers have taken place, the user is instructed to press the RETURN key. After he presses the key, he is presented with a menu of result options as described in Section 4.8. This concludes the result calculation process.

4.8 Result Display

At the end of the result calculation process, the Aid automatically presents the user with an opportunity to review the results which have been calculated. Alternatively, if results were previously calculated, the user can request an opportunity to examine the results by selecting option 5 from either of the title pages in Figures 4-10 and 4-12, as depicted by Figure 4-86. In either event the user is presented with the menu of result options shown in Figure 4-87.

```
                    Department of Defense
              Advanced Research Projects Agency
         (Information Processing Technology Office)

      SATELLITE SURVEILLANCE AVOIDANCE OPTIMIZATION AID

                        developed by
                   Decisions & Designs, Inc.

OPTIONS:

(1)  Introduction
(2)  Define new transit plan
(3)  Review/edit transit plan
(4)  Review environmental parameters
(5)  Review results
(6)  Stop execution

Enter number of option desired:  5
```

Figure 4-86

With the exception of option 5, each of the options in this menu allows the user to examine some aspect of the results calculated for the specified transit. Selecting option 5, as shown in Figure 4-88, indicates that no further review of results is desired and causes the title page of Figure 4-12 to appear upon the screen. Each of the other options is discussed in turn in Sections 4.8.1 through 4.8.4 below.

4.8.1 Recommended SOA Profile - If the user selects option 1 from the result option menu, as shown in Figure 4-89, the Aid will display for him the principal result produced by the optimization process, namely the recommended (optimal) SOA profile. The form of this display is illustrated in Figure 4-90. This information must be used by the naval commander to govern the progress of his task force along the planned route in order to minimize the cost of detection by extant surveillance satellites.

```
RESULT OPTIONS:

(1) Recommended SOA Profile
(2) Detection Zones under Recm'd SOA Profile
(3) Intercept Avoidance Profile
(4) Potential Detection Zones
(5) None of the above

Enter number of option desired:
```

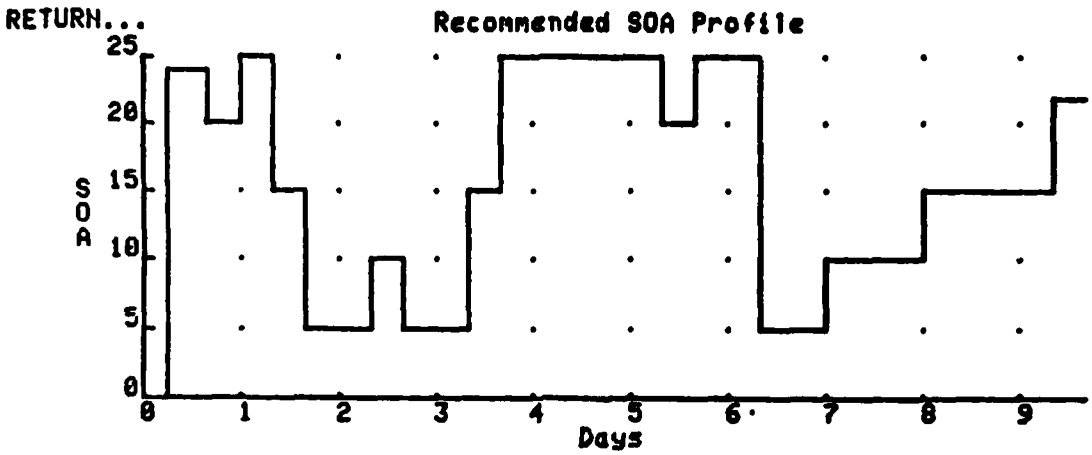
Figure 4-87

```
RESULT OPTIONS:

(1) Recommended SOA Profile
(2) Detection Zones under Recm'd SOA Profile
(3) Intercept Avoidance Profile
(4) Potential Detection Zones
(5) None of the above

Enter number of option desired:  5
```

Figure 4-88

```
RESULT OPTIONS:

(1) Recommended SOA Profile
(2) Detection Zones under Recm'd SOA Profile
(3) Intercept Avoidance Profile
(4) Potential Detection Zones
(5) None of the above

Enter number of option desired:  1
```

Figure 4-89



Date-Time	SOA
17 NOV 0600	24
17 NOV 1600	20
18 NOV 0000	25
18 NOV 0800	15
18 NOV 1600	5
19 NOV 0000	5
19 NOV 0800	10
19 NOV 1600	5
20 NOV 0000	5
20 NOV 0800	15
20 NOV 1600	25
21 NOV 0000	25

Date-Time	SOA
21 NOV 0800	25
21 NOV 1600	25
22 NOV 0000	25
22 NOV 0800	20
22 NOV 1600	25
23 NOV 0000	25
23 NOV 0800	5
23 NOV 1600	5
24 NOV 0000	10
24 NOV 0800	10
24 NOV 1600	10
25 NOV 0000	15

Date-Time	SOA
25 NOV 0800	15
25 NOV 1600	15
26 NOV 0000	15
26 NOV 0800	22

Figure 4-90

The SOA profile is presented both in a histogram form and in a tabular form. Note that the origin of the time axis of the histogram corresponds to midnight preceding the time of departure; the SOA plot assumes a value different from zero at the time of departure and subsequently changes only at times which are multiples of the time increment specified by the user for SOA changes (Section 4.4.5).

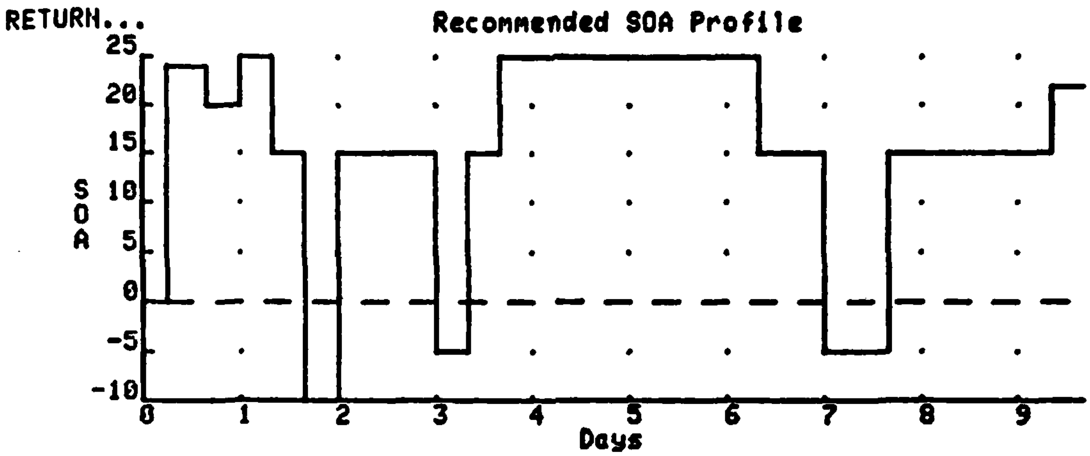
The first entry in the table indicates the SOA to be employed at the time of departure, and each subsequent entry specifies the SOA to be used for successive times which are multiples of the time increment for SOA changes.

As shown in Figure 4-90, the SOAs recommended for the first and the last time increments might not correspond exactly to one of the specified SOA options (Section 4.4.4). For that matter the durations of the first and last time increments might not equal the specified time increment for SOA changes. These discrepancies are discussed in Section 3.0.

If negative SOA options have been allowed by the user, the SOA profile histogram will appear as shown in Figure 4-91 with the SOA axis origin shifted, but no other differences will occur.

When the user has concluded his perusal of the SOA data, he may press the RETURN key in response to the "RETURN..." request which appears in the upper left corner of the screen, and the result option menu of Figure 4-87 will reappear.

4.8.2 Detection Zones Under Recommended SOA Profile - Even when the naval commander adheres to the SOA profile recommended by the optimization process, his task force is likely to encounter satellite intercepts which are unavoidable



Date-Time	SOA
17 NOV 0600	24
17 NOV 1600	20
18 NOV 0000	25
18 NOV 0800	15
18 NOV 1600	-10
19 NOV 0000	15
19 NOV 0800	15
19 NOV 1600	15
20 NOV 0000	-5
20 NOV 0800	15
20 NOV 1600	25
21 NOV 0000	25
21 NOV 0800	25
21 NOV 1600	25
22 NOV 0000	25
22 NOV 0800	25
22 NOV 1600	25
23 NOV 0000	25
23 NOV 0800	15
23 NOV 1600	15
24 NOV 0000	-5
24 NOV 0800	-5
24 NOV 1600	15
25 NOV 0000	15
25 NOV 0800	15
25 NOV 1600	15
26 NOV 0000	15
26 NOV 0800	22

Figure 4-91

or which are avoidable only at the expense of encountering a more costly intercept. (See Section 3.0). The significance of a satellite intercept is that it represents a point along the transit where detection by a satellite is possible, that is, a point for which the transiting force lies within a satellite footprint. It is important to note that merely lying within the footprint does not mean that detection by the satellite is certain or even likely. The satellite may not be in operation, the weather may be unsuitable for detection, or an evasive action might thwart detection.

For this latter reason it is important for the naval commander to know where (and when) all such intercepts will occur along his transit route. The optimization process selects for each intercept the best evasive action to employ and assumes that the naval commander will in fact employ it.

By selecting option 2 from the result option menu, as shown in Figure 4-92, the user will be given a display image which indicates what intercepts will be encountered and the evasive action recommended for each. Figure 4-93 contains an example of such a display image.

```
RESULT OPTIONS:

(1) Recommended SOA Profile
(2) Detection Zones under Recm'd SOA Profile
(3) Intercept Avoidance Profile
(4) Potential Detection Zones
(5) None of the above

Enter number of option desired:  2
```

Figure 4-92

The plot on the top half of the display represents the route of the ship. The small circles super-imposed upon it represent the intercepts that will be encountered when

RETURN...   Detection Zones under Recm'd SOA Profile

No	ID	Lat	Lng	Date/Time	Expos	Action
1	E	37.4N	72.0W	17 NOV 1433	2.3	EMCON
2	I	37.6N	68.5W	17 NOV 2241	0.8	NORMAL OPERATIONS
3	C	37.7N	67.2W	18 NOV 0129	2.0	EMCON
4	C	37.8N	60.3W	19 NOV 0047	2.0	EMCON
5	C	37.7N	58.7W	19 NOV 1201	2.0	EMCON
6	E	35.0N	36.3W	22 NOV 0209	2.3	EMCON
7	E	33.9N	31.8W	22 NOV 1207	2.3	EMCON
8	O	31.0N	22.8W	23 NOV 1022	1.1	NORMAL OPERATIONS
9	O	30.7N	21.9W	23 NOV 2003	1.1	NORMAL OPERATIONS
10	C	31.1N	17.8W	24 NOV 2204	2.0	EMCON
11	C	32.3N	15.0W	25 NOV 0915	2.0	EMCON
12	E	34.0N	11.1W	25 NOV 2355	2.3	EMCON

Figure 4-93

the recommended SOA profile (Section 4.8.1) is employed. Associated with each small circle is an intercept number, assigned in increasing order from point of departure to destination, and the type code of the satellite involved in the intercept.

In the table on the bottom half of the display, more specific information about each intercept is provided. The number and the type code (ID) in each row of the table match the corresponding items of an intercept on the ship track plot. Each row of the table provides the coordinates and the time of an intercept, the amount of time in minutes that the transiting force will be exposed to possible detection by the satellite, and the evasive action recommended to thwart detection.

With this table the naval commander has everything he needs to know about when and where intercepts will occur and what evasive action will best minimize the possibility of detection.

When the user has finished his review of the detection zone data, he may press the RETURN key in response to the "RETURN..." request which appears in the upper left corner of the screen, and the result option menu of Figure 4-87 will reappear.

4.8.3 Intercept Avoidance Profile - If the user wishes to view expected intercepts within the context of all those intercepts that will be avoided by adhering to the recommended SOA profile, he may select option 3 from the result option menu as shown in Figure 4-94. This will cause the intercept avoidance profile of Figure 4-95 to appear upon the screen.

RESULT OPTIONS:

(1) Recommended SOA Profile
(2) Detection Zones under Recm'd SOA Profile
(3) Intercept Avoidance Profile
(4) Potential Detection Zones
(5) None of the above

Enter number of option desired: 3

Figure 4-94

The intercept avoidance profile is discussed in detail in Sections 2.0 and 3.0. Briefly, the vertical lines represent intercepts of satellites with the planned transit route; the parallelogram represents the minimum and maximum SOA constraints; and the irregular line drawn from lower left to upper right represents progress of the transiting force from point of departure to destination when the recommended SOA profile is followed. The intersection of the irregular line with a vertical line represents an intercept as listed in the detection zone table described in Section 4.8.2 above. Distance is expressed in nautical miles.

When the user has completed his review of this display, he may press the RETURN key in response to the "RETURN..." request at the upper left of the screen, and the result option menu of Figure 4-87 will reappear.

4.8.4 <u>Potential Detection Zones</u> - The user may wish more specific information about the intercepts plotted on the intercept avoidance profile discussed in Section 4.8.3 (Figure 4-95). If so, he may select option 4 from the result option menu, as shown in Figure 4-96, and the Aid will display a table of all the intercepts, or potential detection zones. For each intercept, the table will indicate the type of satellite, the time of the intercept, and the

RETURN...

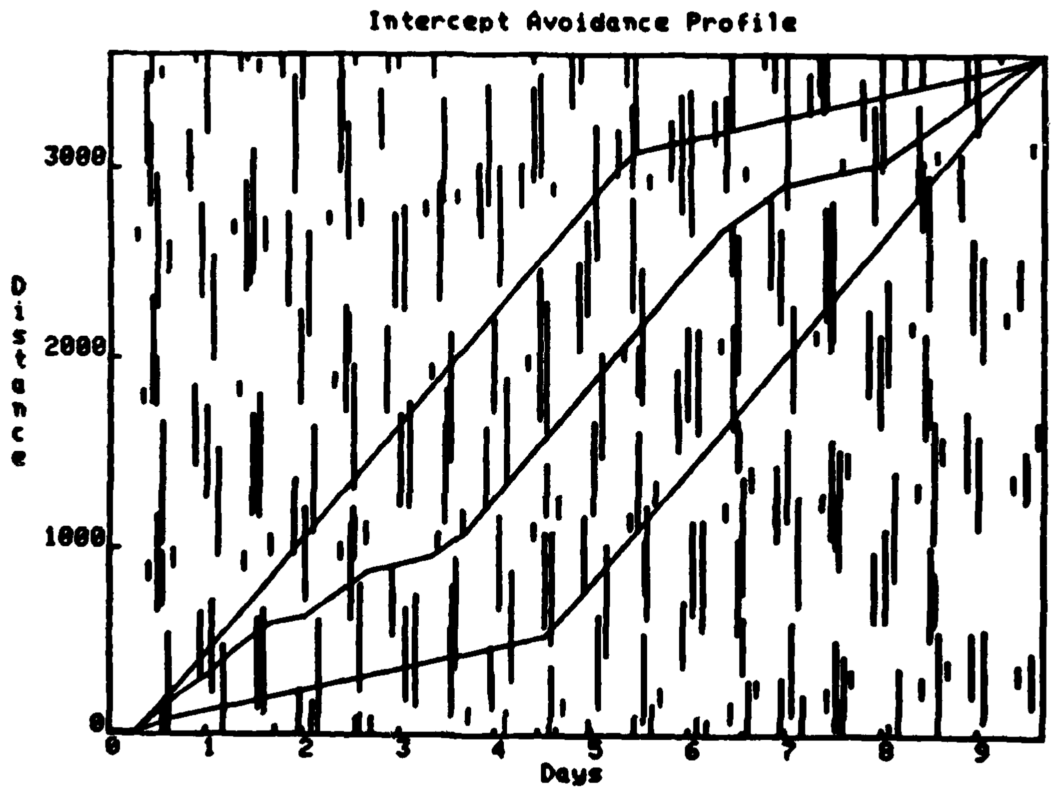


Figure 4-95

```
RESULT OPTIONS:

(1) Recommended SOA Profile
(2) Detection Zones under Recm'd SOA Profile
(3) Intercept Avoidance Profile
(4) Potential Detection Zones
(5) None of the above

Enter number of option desired:  4
```

Figure 4-96

extent (in nautical miles from point of departure) to which it covers the transit route. An example of such a table, which is often quite extensive, is shown in Figures 4-97(a)-(f).

Note that the user can elect not to review additional table segments by responding negatively to the "Next table segment?" query which appears to the upper left of all but the last table segment.

When the user is finished with his review of the potential detection zone table, he must press the RETURN key in response to the "RETURN..." request which appears at the upper left of the screen. The result option menu of Figure 4-87 will then reappear.

4.9 Termination of Execution

Execution of the Aid can be terminated any time that one of the title pages of Figures 4-10, 4-11, or 4-12 is on the screen. This means that execution can be interrupted even before result calculation has taken place.

When the user selects option 6 from the title page menu, the Aid terminates communication with the host, if

Next table segment? y Potential Detection Zones

No	Type	Date-Time	Coverage
1	R	17 NOV 0633	2611-2672
2	R	17 NOV 0805	1758-1828
3	C	17 NOV 0902	3019-3511
4	R	17 NOV 0935	835- 924
5	O	17 NOV 0952	2801-3225
6	I	17 NOV 0957	2798-3128
7	E	17 NOV 1006	3461-3615
8	C	17 NOV 1030	1765-2317
9	O	17 NOV 1125	1751-2003
10	I	17 NOV 1131	1759-1951
11	E	17 NOV 1134	2265-2960
12	C	17 NOV 1158	672-1172
13	R	17 NOV 1253	3480-3542
14	O	17 NOV 1258	702- 979
15	I	17 NOV 1304	715- 928
16	E	17 NOV 1304	1027-1658
17	C	17 NOV 1325	0- 133
18	R	17 NOV 1424	2447-2609
19	E	17 NOV 1433	0- 549
20	R	17 NOV 1552	901-1004
21	O	17 NOV 1933	2945-3190
22	I	17 NOV 1939	2877-3061
23	O	17 NOV 2104	1526-1852
24	C	17 NOV 2108	3569-3615
25	I	17 NOV 2109	1435-1602
26	O	17 NOV 2236	382- 658
27	C	17 NOV 2236	2318-2803
28	I	17 NOV 2241	306- 514
29	E	17 NOV 2356	3185-3615
30	C	18 NOV 0002	1265-1745
31	E	18 NOV 0125	1992-2532
32	C	18 NOV 0129	226- 726
33	E	18 NOV 0253	960-1520
34	E	18 NOV 0422	0- 488
35	R	18 NOV 0628	2658-2718
36	R	18 NOV 0800	1805-1875
37	C	18 NOV 0821	3532-3615
38	R	18 NOV 0930	890- 978
39	C	18 NOV 0947	2368-2929
40	E	18 NOV 0955	3585-3615
41	O	18 NOV 1028	2387-2633
42	I	18 NOV 1033	2389-2575
43	C	18 NOV 1116	1188-1701
44	E	18 NOV 1123	2446-3097
45	O	18 NOV 1201	1351-1610
46	I	18 NOV 1207	1362-1560
47	C	18 NOV 1243	142- 628
48	R	18 NOV 1248	3522-3585
49	E	18 NOV 1253	1168-1810
50	O	18 NOV 1334	267- 559
51	I	18 NOV 1339	280- 585
52	R	18 NOV 1420	2570-2736
53	E	18 NOV 1423	111- 602
54	R	18 NOV 1547	964-1070
55	R	18 NOV 1717	0- 42
56	O	18 NOV 1835	3562-3615
57	I	18 NOV 1841	3493-3615
58	O	18 NOV 2009	2386-2759
59	I	18 NOV 2014	2282-2564
60	O	18 NOV 2140	1056-1359

Figure 4-97(a)

Next table segment? y Potential Detection Zones

No	Type	Date-Time	Coverage
61	I	18 NOV 2145	972-1201
62	C	18 NOV 2154	2871-3495
63	O	18 NOV 2312	0- 245
64	I	18 NOV 2317	0- 107
65	C	18 NOV 2321	1763-2243
66	E	18 NOV 2344	3371-3615
67	C	19 NOV 0047	731-1217
68	E	19 NOV 0114	2124-2663
69	C	19 NOV 0215	0- 177
70	E	19 NOV 0242	1090-1646
71	E	19 NOV 0411	14- 623
72	R	19 NOV 0623	2705-2765
73	R	19 NOV 0755	1853-1921
74	C	19 NOV 0906	2977-3469
75	R	19 NOV 0925	945-1031
76	O	19 NOV 0932	3202-3605
77	I	19 NOV 0937	3206-3522
78	C	19 NOV 1033	1720-2270
79	O	19 NOV 1104	1983-2232
80	I	19 NOV 1110	1989-2178
81	E	19 NOV 1111	2634-3233
82	C	19 NOV 1201	632-1131
83	O	19 NOV 1237	944-1214
84	E	19 NOV 1242	1313-1968
85	I	19 NOV 1243	957-1163
86	R	19 NOV 1243	3564-3615
87	C	19 NOV 1328	0- 94
88	O	19 NOV 1410	0- 111
89	E	19 NOV 1411	238- 816
90	R	19 NOV 1415	2699-2829

No	Type	Date-Time	Coverage
91	I	19 NOV 1415	0- 51
92	R	19 NOV 1542	1030-1137
93	R	19 NOV 1712	14- 92
94	O	19 NOV 1912	3176-3421
95	I	19 NOV 1917	3108-3293
96	O	19 NOV 2044	1822-2165
97	I	19 NOV 2049	1727-1985
98	C	19 NOV 2111	3521-3615
99	O	19 NOV 2215	622- 907
100	I	19 NOV 2220	543- 758
101	C	19 NOV 2239	2276-2761
102	E	19 NOV 2333	3550-3615
103	C	20 NOV 0006	1225-1706
104	E	20 NOV 0103	2256-2795
105	C	20 NOV 0133	185- 686
106	E	20 NOV 0231	1220-1773
107	E	20 NOV 0400	156- 756
108	R	20 NOV 0618	2753-2826
109	R	20 NOV 0750	1900-1968
110	C	20 NOV 0824	3492-3615
111	R	20 NOV 0920	999-1084
112	C	20 NOV 0951	2310-2885
113	O	20 NOV 1007	2626-2924
114	I	20 NOV 1012	2625-2812
115	E	20 NOV 1100	2824-3366
116	C	20 NOV 1119	1139-1657
117	O	20 NOV 1140	1584-1838
118	I	20 NOV 1146	1593-1787
119	E	20 NOV 1230	1460-2130
120	R	20 NOV 1238	3606-3615

Figure 4-97(b)

Next table segment? y Potential Detection Zones

No	Type	Date-Time	Coverage
121	C	20 NOV 1247	103- 500
122	O	20 NOV 1313	523- 806
123	I	20 NOV 1319	536- 754
124	E	20 NOV 1400	367- 951
125	R	20 NOV 1410	2017-2075
126	R	20 NOV 1537	1097-1206
127	R	20 NOV 1707	63- 143
128	O	20 NOV 1949	2752-3018
129	I	20 NOV 1954	2642-2890
130	O	20 NOV 2119	1323-1640
131	I	20 NOV 2124	1236-1474
132	C	20 NOV 2157	2815-3443
133	O	20 NOV 2251	212- 483
134	I	20 NOV 2256	137- 342
135	C	20 NOV 2324	1723-2203
136	C	21 NOV 0051	691-1178
137	E	21 NOV 0051	2390-3009
138	C	21 NOV 0218	0- 136
139	E	21 NOV 0220	1350-1899
140	E	21 NOV 0349	296- 888
141	R	21 NOV 0613	2800-3019
142	R	21 NOV 0745	1947-2014
143	C	21 NOV 0909	2935-3420
144	O	21 NOV 0911	3560-3615
145	R	21 NOV 0916	1052-1136
146	I	21 NOV 0917	3580-3615
147	C	21 NOV 1037	1676-2223
148	O	21 NOV 1043	2217-2464
149	R	21 NOV 1045	0- 30
150	I	21 NOV 1049	2220-2408

No	Type	Date-Time	Coverage
151	E	21 NOV 1049	2956-3497
152	C	21 NOV 1205	593-1091
153	O	21 NOV 1217	1182-1445
154	E	21 NOV 1219	1613-2297
155	I	21 NOV 1222	1193-1394
156	C	21 NOV 1332	0- 54
157	E	21 NOV 1349	497-1089
158	O	21 NOV 1349	75- 376
159	I	21 NOV 1354	80- 319
160	R	21 NOV 1405	2062-2920
161	E	21 NOV 1518	0- 35
162	R	21 NOV 1532	1165-1270
163	R	21 NOV 1702	114- 194
164	O	21 NOV 1851	3402-3615
165	I	21 NOV 1856	3334-3519
166	O	21 NOV 2024	2141-2500
167	I	21 NOV 2029	2040-2312
168	C	21 NOV 2115	3473-3615
169	O	21 NOV 2155	870-1165
170	I	21 NOV 2200	789-1011
171	C	21 NOV 2243	2235-2719
172	O	21 NOV 2327	0- 75
173	C	22 NOV 0009	1106-1667
174	E	22 NOV 0040	2525-3220
175	C	22 NOV 0136	144- 647
176	E	22 NOV 0209	1479-2025
177	E	22 NOV 0337	434-1017
178	R	22 NOV 0609	2962-3190
179	R	22 NOV 0740	1994-2061
180	C	22 NOV 0827	3452-3615

Figure 4-97(c)

Next table segment? y Potential Detection Zones

No	Type	Date-Time	Coverage
181	R	22 NOV 0911	1105-1180
182	O	22 NOV 0946	2913-3335
183	I	22 NOV 0952	2910-3242
184	C	22 NOV 0954	2261-2839
185	E	22 NOV 1038	3087-3615
186	R	22 NOV 1040	0- 104
187	O	22 NOV 1119	1815-2067
188	C	22 NOV 1123	1097-1615
189	I	22 NOV 1125	1823-2014
190	E	22 NOV 1207	1770-2470
191	C	22 NOV 1250	64- 549
192	O	22 NOV 1253	770-1045
193	I	22 NOV 1258	783- 994
194	E	22 NOV 1338	629-1229
195	R	22 NOV 1400	2907-2965
196	E	22 NOV 1506	0- 165
197	R	22 NOV 1527	1236-1351
198	R	22 NOV 1657	164- 246
199	O	22 NOV 1927	3010-3254
200	I	22 NOV 1933	2941-3126
201	O	22 NOV 2059	1606-1937
202	I	22 NOV 2104	1515-1764
203	C	22 NOV 2201	2770-3392
204	O	22 NOV 2230	448- 727
205	I	22 NOV 2235	371- 581
206	C	22 NOV 2327	1683-2163
207	E	23 NOV 0029	2661-3419
208	C	23 NOV 0054	651-1140
209	E	23 NOV 0157	1608-2153
210	C	23 NOV 0221	0- 94
211	E	23 NOV 0326	569-1146
212	E	23 NOV 0455	0- 73
213	R	23 NOV 0605	3136-3363
214	R	23 NOV 0735	2041-2107
215	R	23 NOV 0906	1157-1238
216	C	23 NOV 0912	2093-3306
217	O	23 NOV 1022	2453-2699
218	E	23 NOV 1027	3216-3615
219	I	23 NOV 1027	2454-2640
220	R	23 NOV 1035	62- 176
221	C	23 NOV 1040	1632-2175
222	O	23 NOV 1156	1416-1673
223	E	23 NOV 1156	1932-2649
224	I	23 NOV 1201	1426-1623
225	C	23 NOV 1208	553-1050
226	E	23 NOV 1326	762-1372
227	O	23 NOV 1328	339- 629
228	I	23 NOV 1334	352- 575
229	C	23 NOV 1335	0- 15
230	R	23 NOV 1355	2952-3010
231	E	23 NOV 1455	0- 295
232	R	23 NOV 1522	1309-1426
233	R	23 NOV 1652	216- 299
234	I	23 NOV 1835	3554-3615
235	O	23 NOV 2003	2485-2044
236	I	23 NOV 2008	2370-2665
237	C	23 NOV 2118	3424-3615
238	O	23 NOV 2134	1129-1436
239	I	23 NOV 2139	1044-1275
240	C	23 NOV 2246	2193-2677

Figure 4-97(d)

Next table segment? y Potential Detection Zones

No	Type	Date-Time	Coverage
241	O	23 NOV 2306	45- 310
242	I	23 NOV 2312	0- 172
243	C	24 NOV 0012	1147-1628
244	E	24 NOV 0017	2799-3608
245	C	24 NOV 0139	103- 607
246	E	24 NOV 0146	1738-2201
247	E	24 NOV 0315	703-1274
248	E	24 NOV 0444	0- 217
249	R	24 NOV 0600	3299-3517
250	R	24 NOV 0730	2087-2153
251	C	24 NOV 0831	3412-3615
252	R	24 NOV 0901	1209-1289
253	O	24 NOV 0926	3307-3615
254	I	24 NOV 0931	3314-3615
255	C	24 NOV 0957	2212-2792
256	E	24 NOV 1016	3343-3615
257	R	24 NOV 1030	134- 246
258	O	24 NOV 1058	2048-2296
259	I	24 NOV 1104	2053-2242
260	C	24 NOV 1126	1056-1571
261	E	24 NOV 1144	2100-2828
262	O	24 NOV 1232	1011-1278
263	I	24 NOV 1237	1023-1228
264	C	24 NOV 1253	25- 509
265	E	24 NOV 1315	897-1517
266	R	24 NOV 1350	2996-3055
267	O	24 NOV 1404	0- 105
268	I	24 NOV 1409	0- 127
269	E	24 NOV 1444	0- 425
270	R	24 NOV 1510	1304-1504

No	Type	Date-Time	Coverage
271	R	24 NOV 1647	267- 351
272	O	24 NOV 1906	3240-3485
273	I	24 NOV 1911	3171-3356
274	O	24 NOV 2038	1909-2255
275	I	24 NOV 2043	1012-2074
276	C	24 NOV 2204	2726-3339
277	O	24 NOV 2210	690- 978
278	I	24 NOV 2215	611- 828
279	C	24 NOV 2331	1643-2123
280	E	25 NOV 0007	2999-3615
281	C	25 NOV 0057	612-1101
282	E	25 NOV 0135	1869-2410
283	C	25 NOV 0225	0- 52
284	E	25 NOV 0304	836-1401
285	E	25 NOV 0432	0- 357
286	R	25 NOV 0555	3450-3615
287	R	25 NOV 0725	2134-2199
288	R	25 NOV 0856	1260-1339
289	C	25 NOV 0915	2849-3344
290	O	25 NOV 1001	2693-3043
291	E	25 NOV 1005	3468-3615
292	I	25 NOV 1006	2691-2936
293	R	25 NOV 1025	205- 313
294	C	25 NOV 1043	1587-2129
295	E	25 NOV 1133	2275-2968
296	O	25 NOV 1135	1640-1902
297	I	25 NOV 1140	1657-1850
298	C	25 NOV 1211	514-1010
299	E	25 NOV 1304	1036-1666
300	O	25 NOV 1308	592- 873

Figure 4-97(e)

RETURN...

Potential Detection Zones

No	Type	Date-Time	Coverage
301	I	25 NOV 1313	606- 821
302	R	25 NOV 1345	3041-3099
303	E	25 NOV 1433	0- 557
304	R	25 NOV 1513	1461-1584
305	R	25 NOV 1642	319- 405
306	O	25 NOV 1943	2839-3084
307	I	25 NOV 1948	2748-2957
308	O	25 NOV 2113	1400-1720
309	I	25 NOV 2118	1312-1553
310	C	25 NOV 2122	3375-3615
311	O	25 NOV 2245	277- 550
312	C	25 NOV 2249	2151-2635
313	I	25 NOV 2250	202- 408
314	E	25 NOV 2355	3196-3615
315	C	26 NOV 0015	1107-1589
316	E	26 NOV 0124	1999-2539
317	C	26 NOV 0143	61- 567
318	R	26 NOV 0551	3591-3615
319	R	26 NOV 0720	2181-2246
320	R	26 NOV 0851	1310-1388
321	R	26 NOV 1021	273- 379
322	O	26 NOV 1037	2282-2529
323	I	26 NOV 1043	2285-2472
324	O	26 NOV 1211	1247-1508
325	I	26 NOV 1216	1258-1458
326	R	26 NOV 1340	3085-3144
327	O	26 NOV 1343	149- 447
328	I	26 NOV 1349	162- 392
329	R	26 NOV 1508	1542-1660
330	R	26 NOV 1637	372- 459
331	O	26 NOV 1845	3464-3615
332	I	26 NOV 1850	3395-3581
333	O	26 NOV 2018	2233-2597
334	I	26 NOV 2023	2131-2408
335	O	26 NOV 2149	941-1239
336	I	26 NOV 2154	858-1083
337	O	26 NOV 2321	0- 140
338	I	26 NOV 2327	0- 3

Figure 4-97(f)

necessary, saves certain status information on the program tape cartridge, rewinds the tape cartridge, and prints an "Execution terminated" message on the screen as shown in Figure 4-98. At this point the user may remove the tape cartridge from the 4051 tape slot (by pushing the EJECT button) and turn the power off.

```
                    Department of Defense
             Advanced Research Projects Agency
        (Information Processing Technology Office)

      SATELLITE SURVEILLANCE AVOIDANCE OPTIMIZATION AID

                        developed by
                  Decisions & Designs, Inc.
OPTIONS:

(1)  Introduction
(2)  Define new transit plan
(3)  Review/edit transit plan
(4)  Review environmental parameters
(5)  Calculate  results
(6)  Stop execution

Enter number of option desired:  6

Execution terminated
```

Figure 4-98

4.10 Error Conditions

The Aid is forgiving of errors made by the user in response to queries which require parameter values or option numbers. Every user entry is checked by the Aid for correct syntax. Furthermore, every syntactically correct entry is checked to ensure that its value lies within the range of permissible values.

Whenever the user enters a value which is syntactically incorrect or which lies outside the range of allowable values, the Aid prints an error message, such as

*** Invalid entry; value must be between 0 and 100 - try again.

and requests the value again.

In many cases, once an acceptable value has been provided by the user, the Aid requests confirmation that the value is the one actually intended by the user. This gives the user a chance to change his mind or to correct an entry without having to request an opportunity to make the change.

As a result of these features, the Aid is very robust; the user never has to worry that a typing error or a temporary lapse in attention will cause the Aid to crash or abort.

INTELLIGENCE

Rationale for Weights

Intelligence tasks D and G provide over 87% of the total improvement in intelligence tasks. Intel D, Receive/Record, and Intel G, Disseminate, are time- and manpower-consuming tasks. Intel G is very valuable to improve because the status quo is very poor. Intel D receives the highest weight for importance to improve. The ability to sort and organize large amounts of information is very important, especially in fast-moving situations. The officers want to have these two tasks automated so that they will have time to perform the remaining tasks manually.

Performing Intel A, Determine Requirements, takes a long time to acquire and organize the materials required for estimate preparation. The Ideal Performance gives the capability to react quickly to changing situations. The officers preferred to manually identify gaps in information and produce EEI/OIRs.

Both Intel B, Collection Planning and Intel C, Supervise Collection, are considered manual tasks. The officers had no faith in the ability to automatically generate EEIs; and once the EEIs are determined, automation is of no further value. Intel E, Initial Processing, is an important task, but one that can be handled manually. Highlighting possibly significant information is a desirable feature of the ideal performance.

A desirable feature of the ideal performance for Intel F, Interpret, is the capability to display possible enemy courses of action in time-phase sequence to determine the effect on our own situation or course of action. Changes in enemy capabilities and vulnerability are better done manually.

Intelligence Functions

Intel A Determine Requirements.

Task: Analyze command mission and necessary tactical action; determine basic intelligence requirements and EEI's for planning and execution of operations; include requirements developed by subordinate and other agencies. Prepare and disseminate initial intelligence estimate.

Status Quo

Charts & available imagery assembled... analysts obtain available area/enemy info from studies, reports, etc.... basic files established...mission and available info analyzed...requirements of staff gathered...basic intel requirements & EEI's developed & recommended to Cdr; process is manual. Oral or written initial intel. estimate manually prepared and disseminated.

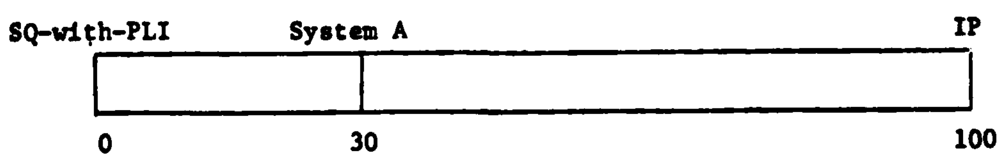
Ideal Performance

Total info available in data base...digitized map available for display...capability to reflect area by terrain characteristics, anticipated weather patterns, etc.. capable of displaying current & historical enemy activity data...data base contains complete cross-reference capability...can display graphic or text history...files generated automatically...gaps in info automatically identified & tentative EEI/OIR's produced. Initial intel estimate automatically formatted & generated from data base.

System A

Same as Ideal except:

1. Data base constructed from NIPS.
2. No digitized map.
3. No capability to reflect area by terrain characteristics.
4. Requires man/machine interface to display data, produce map overlay, and determine gaps in information.



Rationale

Most valuable System A improvement to initial intelligence estimate.

Intel B Collection Planning.

Task: Prepare plans and orders, and requests to higher, adjacent, and lower headquarters, for the collection of information.

Status Quo

Based on EEI and OIR, collection plan is written ... tasks to organic collection assets included...requests to higher/adjacent transmitted by letter, MSG, radio, etc.

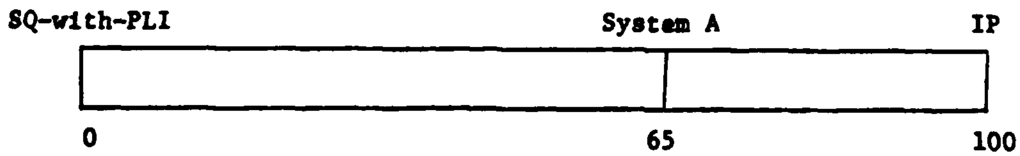
Ideal Performance

System contains capabilities of available collection assets & predetermined assignment parameters...system automatically generates collection plan ready for distribution...task assignments to organic agencies or requests to higher/adjacent agencies developed...system automatically maintains files/records... hard copy available on demand.

System A

Same as Ideal except:

1. System does not contain capabilities of collection assets or parameters.
2. Requires man/machine interface to determine info gaps, recommend tasking of agencies, generate collection plan, and maintain files/records.



Rationale

The main System A improvement is maintenance of files and records.

Intel C Supervise Collection.

Task: Supervise & coordinate the information collection effort.

Status Quo

Based on collection plan--direct, supervise, & coordinate collection effort via MSG, liaison & staff visits... based on responses, generate additional EEI's...upon approval, incorporate into collection plan & write orders & requests for same.

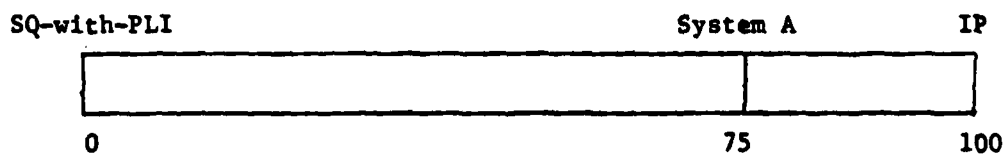
Ideal Performance

System automatically prompts agencies for timely responses...additional EEI's generated automatically within parameters or entered manually... collection plan updated & orders/requests generated automatically.

System A

Same as Ideal except:

1. System does not prompt agencies.
2. Requires man/machine interface to generate orders/requests and update collection plan.



Rationale

Not prompting agencies is a good feature. Automatic generation of EEI's may not be desirable. Score of 75 reflects man/machine interface.

Intel D Receive/Record.

Task: Receive, record, maintain, and display, as appropriate, all items of information received. Prepare and submit reports as required.

Status Quo

All info is read...similarities w/other info is reviewed...transferred to recording media...plotted on situation map or display boards and incorporated into basic files...reports prepared manually with pictorial graphic information included as required.

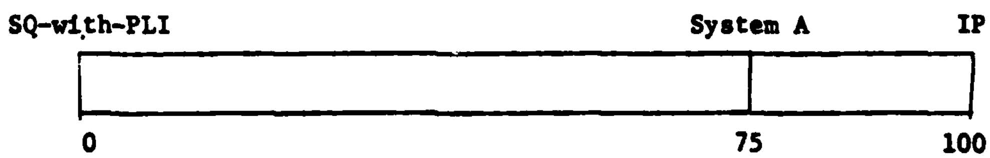
Ideal Performance

All info received and cross-referenced in a data base continually updated to avoid duplication and to purge data which is no longer relevant...current information displayed alphanumerically along with history of area, unit, type activity, etc...plotted by symbol on sit map automatically on demand...capability to display history in particular area by time phase...capability to display history of activity by categories... hard copy of alphanumeric or symbology available on demand...formatted reports generated automatically or on demand, ready for distribution.

System A

Same as Ideal except:

1. Requires man/machine interface to enter info in data base and display area.
2. Plots manually (grease pencil) on map overlay.



Rationale

Automated data input would be very valuable because of time saving and reduction in errors currently caused by multiple handling of data.

Intel E Initial Processing.

Task: Evaluate, analyze, and integrate items of information to form a picture of enemy activity or the area of operations which might influence the commander's decision.

Status Quo

Recorded info is evaluated for pertinence, urgency, reliability & accuracy... info is then analyzed to isolate significant elements...elements then integrated to form hypotheses concerning area of operations and/or the enemy situation.

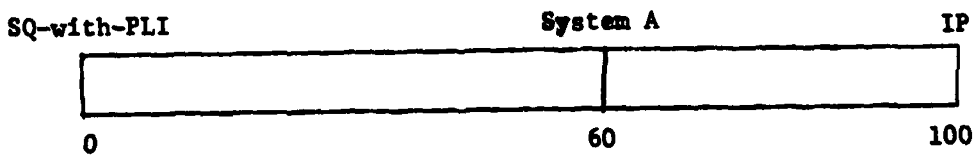
Ideal Performance

System automatically highlights possible significant info IAW established parameters...data kept on reliability of source/agency...all background/history available in data base & integrated automatically for display... hypotheses generated automatically IAW established parameters.

System A

Same as Ideal except:

1. Does not automatically highlight info.
2. Requires man/machine interface to display and generate info.



Rationale

Capability to automatically highlight information is valuable.

Intel F Interpret.

Task: Interpret information to determine its significance, meaning, and effect on the friendly situation/planned activity. Develop target intelligence.

Status Quo

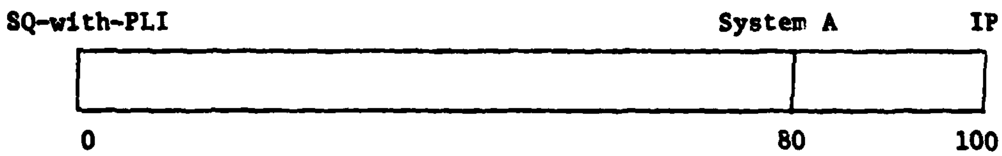
Info leading to various hypotheses is interpreted to determine significance... determination of impact of intelligence on enemy capabilities, vulnerability, & possible courses of action...impact on own c/a assessed...additional EEI/OIR developed as necessary.

Ideal Performance

System automatically displays change in enemy capabilities/vulnerability IAW established parameters...possible enemy c/a can be displayed in time-phase sequence to determine effect on own situation or course of action...additional EEI/OIR generated automatically within parameters or entered manually.

Same as Ideal except:

System A — 1. Requires man/machine interface to display data.



Rationale

Score of 80 reflects man/machine interface deficiency.

Intel G Disseminate.

Task: Disseminate current intelligence to the units/agencies needing it. Update intel estimate as required.

Status Quo

Intel put in proper form for dissemination via MSG, summary, courier, etc... critical intel disseminated in manually selected format. Manually update intel estimate as required.

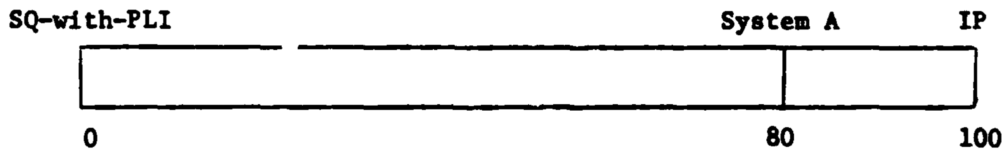
Ideal Performance

System selects report type automatically or through operator input...MSG, summary etc. generated automatically... hard copy of text and/or graphics available on demand...update of intel estimate.

Same as Ideal except:

System A

1. Requires man/machine interface to generate data.



Rationale

Score of 80 reflects man/machine interaction deficiency. Officers were concerned about disseminating garbage. There is a need for quality control.

APPENDIX D

Operational Area Task Summaries

Combat Operations Center

Task Summary: Develop operations, plans, and orders for ground maneuver elements; allocate assets; monitor status of friendly and enemy forces; supervise execution of operational orders, monitor progress in achieving objectives, and coordinate with adjacent units; ensure integration of all fire support means with scheme of maneuver; receive/initiate tactical alerts.

Status Quo Summary

Tasks predominantly performed manually; manually maintained status boards and maps updated from real-time friendly unit position location information; message/verbal reports of varying timeliness; manual review and decision making; manual reporting and record keeping.

System "A" Summary

Graphic/text displays from automated data base; automatic real-time friendly unit location and status displays; automated assistance in operations planning; simulation capability for possible courses of action; automated assistance in report preparation and automatic forwarding, retention, and cross referencing of reports; automated assistance in identification/resolution of conflicts/coordination requirements; tactical alerts automatically disseminated.

Direct Air Support Center

Task Summary: Receive and coordinate requests for scheduled and immediate DAS; process BDA and intelligence information; monitor and coordinate execution of DAS operations; assist in coordination of FAAD operations; coordinate ASRT targeting.

Status Quo Summary

DAS mission requests received, manually plotted and analyzed; manually maintained status boards; voice liaison/coordination with fire support agencies; manual processing of BDA and intelligence information; friendly unit position location information automatically received and used to manually update plots and maps; manual plotting of restrictive and control measures; voice briefing to A/C; voice/MSG updates to requesting agencies; manual processing of air defense information/requirements; manually analyze and prepare mission briefings on ASRT targets.

System "A" Summary

Automated graphic/text displays of information in data base; DAS missions entered into data base and disseminated as required; tentative flight profiles automatically generated; BDA/intelligence entered into data base is automatically disseminated/retained as required; friendly ground unit and A/C position location information automatically received and displayed; full information on supporting arms activity displayed/available; voice contact with A/C and terminal control agencies; direct passing of air defense information to/from FAAD units; flight profiles to/from ASRT targets automatically generated.

Fire Direction Center

Task Summary: Prepare fire plans including nuclear/chemical fires; maintain current ground situation information; receive and process target damage assessments; perform tactical fire direction; perform target information functions; perform technical fire direction.

Status Quo Summary

Manual preparation of plans, limited automation of firing data calculations (i.e., FADAC); manually maintained status boards and maps updated from real-time friendly unit position location information; manual processing of damage assessments and target information; manual monitoring of fire unit status and reporting; technical fire direction predominantly manual.

System "A" Summary

Automated graphic/text displays from current data base; real-time display of friendly position location information; manually maintained fire unit status; automated production of routine reports; automated target file and damage assessment information; automated calculation of technical fire control solutions; automated determination of type weapon and volume of fire to engage specified targets or schedule of targets.

Fire Support Coordination Center

Task Summary: Develop overall and detailed fire and air support plans to support the scheme/plan of defense; select and recommend appropriate restrictive and control measures; receive and disseminate target information; monitor and coordinate execution of approved fire and air support missions.

Status Quo Summary

Manual planning processes requiring reference to multiple information sources; restrictive and control measures manually determined and promulgated; target information received from multiple sources, manually evaluated, acted upon and/or filed for reference; manually maintained status boards and maps updated from real-time friendly unit position location information; manual verification/approval of missions, resolution of conflicts and issuance of instructions.

System "A" Summary

Automated graphic/text displays from current data base; automated assistance in developing schedule of fires and single integrated artillery, NGF, and air support plan; real-time display of friendly unit and A/C position location information; automatic dissemination of restrictive and control measures; automated target file; graphic/text displays of current situation and fire unit status; automatic routing of fire support requests; automatic dissemination of decisions; historical data retained for reference/analysis.

Intelligence

Task Summary: Determine intelligence requirements; plan and supervise the collection effort; record and initially process information received; interpret information; disseminate current intelligence.

Status Quo Summary

Plans and estimates are manually researched, prepared, and disseminated; manual receipt, recording/plotting, and filing of information; manual processing, interpretation, and correlation with other information; dissemination of high priority information by electronic means, other information manually by paper copy; manually maintained records and reference files.

System "A" Summary

Automated data base with graphic/text displays; complete cross reference capability; requirements and collection plans automatically produced; automatic update of data base when new information entered; ad hoc retrieval capability; automated analysis of data within established parameters including possible enemy courses of action; intelligence reports automatically prepared and disseminated.

Logistics

Task Summary: Planning, coordination, and policy formulation by G-4/S-4; requisition, receipt, storage, inventory management, transportation, distribution, and disposal of all classes of supply; preventive maintenance, repair, and evacuation of equipment and material; evacuation and hospitalization of sick, injured, and wounded personnel; management of organic transportation assets; management of facilities, field sanitation, food services, engineer combat services support, and indigenous labor. NOTE: Logistics includes functional areas of G-4/S-4, supply operations, maintenance operations, evacuation and hospitalization, transportation, and services.

Status Quo Summary

Plans manually prepared; most reports manually processed; supply and maintenance have automated system (i.e., SASSY and MIMMS) augmented by manual procedures; status information varies in timeliness, completeness, and accuracy; most status information manually maintained.

System "A" Summary

Automated graphic/text displays from real-time data base; automated statistical and trend analysis of logistics functional areas; current status information displayed on ad hoc basis; automated planning analysis capability; historical data retained for reference/analysis.

Personnel

Task Summary: Planning, coordinating, and monitoring of: current strengths and requirements for replacements; prisoners of war; graves registration; morale and personnel services; civilian employees. Responsible for the preparation of general correspondence and reports, personnel administration, and classified material control.

Status Quo Summary

Manual planning and estimation; reports manually prepared, forwarded and consolidated; automated manpower management system (JUMPS/MMS) augmented by many manual procedures; most personnel administration accomplished manually; manually maintained files and records.

System "A" Summary

Automated graphic/text displays; MAGTF automated data base with relevant information on personnel status and other functional areas under G-1/S-1 cognizance; automated report/correspondence production; automated casualty processing; automated assistance in preparation of unit diary and ad hoc access to unit level data base; automated classified material control procedures.

Tactical Air Operations Center

Task Summary: Detect, identify, and display information on all a/c within its sector; exchange a/c track information with other agencies; plan for and engage enemy air threats; coordinate and execute ECCM and EMCON; control airspace and air traffic within its sector; act as TACC/TAOC back up.

Status Quo Summary

Tracks automatically acquired and maintained with some manual operations required; partially automated exchange of track data; partially automated target evaluation and engagement; manual ECCM and EMCON actions; automated assisted air traffic control; limited TACC/TAOC backup capability. Real-time friendly ground unit position location information available for manual display.

System "A" Summary

Automatic detection/identification with interactive features on graphic/text display; automatic exchange of track information with air control, fire support, and ground command agencies; enemy engagement/weapons control manual, semiautomatic or automatic options; automated ECCM/EMCON; positive control of all a/c in sector; full TACC/TAOC backup capability; automated operator training capability. Real-time friendly ground unit position location information automatically displayed.

Tactical Air Command Center

Task Summary: Establish air defense alert conditions, responsibilities for air defense in overlapping zones, and emission control (EMCON) conditions; maintain current status on the air situation; disseminate operational information to subordinate agencies; manage MACCS operations; manage all MAGTF A/C within the AOA; authorize diversion of A/C; develop and promulgate Frag orders.

Status Quo Summary

Manual evaluation and dissemination of alert condition requirements, coordination of air defense, and EMCON conditions; limited automated displays of current status information augmented by manual procedures; position location information on friendly ground units automatically received and manually plotted/recorded; majority of information to subordinates manually disseminated; manual planning, evaluation, and allocation of A/C assets; manual evaluation and coordination in A/C diversion situations; Frag orders manually developed and disseminated. At MAG/squadron level manual updating of situation information, scheduling, mission planning, pilot briefing/debriefing and records keeping.

System "A" Summary

Graphic/text displays of information in data base; alert conditions automatically disseminated; automatic evaluation of air defense requirements; automatic evaluation and notification of EMCON conditions; automated summary displays of air and ground situation; real-time position location information for friendly ground units automatically displayed; reports automatically generated and disseminated; operational information for subordinates manually inputted and automatically disseminated; manual evaluation and allocation of A/C assets; automatic screening of A/C in divert situations; automated assistance in Frag preparation. At MAG/squadron: graphic/text displays, air situation information, A/C status information, mission planning data, automated scheduling capability, and current operational and intelligence information.

APPENDIX E

Biographical Data

FUNCTIONAL AREA/AGENCY: COC

ASSESSMENT LOCATION: MCB, Camp Pendleton

INTERVIEWEE DATA

RANK

One Lieutenant Colonel
Two Majors

MILITARY OCCUPATIONAL SPECIALTY

0302

CURRENT BILLETS

- XO, Hq Bn, Marine Division
- XO, Infantry Bn

TOTAL CUMULATIVE USMC EXPERIENCE (YEARS): 46 YEARS

REPRESENTATIVE PAST BILLETS:

- Assistant G-3, Marine Division
- S-3/S-3A, Infantry Regt/Bn
- MAF COC Watch Officer
- CO Rifle Company
- Commander Rifle Platoon
- MAU, MAB, MAF, Exercise Participants
- Combat Experience, Viet Nam

FUNCTIONAL AREA/AGENCY: TACC

ASSESSMENT LOCATION: MCAS, El Toro

INTERVIEWEE DATA

RANK

Two Majors
One Warrant Officer

MILITARY OCCUPATIONAL SPECIALTY

7210/7208/7204

CURRENT BILLETS

- Wing Air Control Officer
- XO, MASS
- Air Support Officer, TACC

TOTAL CUMULATIVE USMC EXPERIENCE (YEARS): 45 YEARS

REPRESENTATIVE PAST BILLETS:

- CO/XO, MASS
- OIC, TACC
- CO, LAAM Bn
- MASS, MACS Billets
- TACC Officer/Senior Air Controller
- Operations Officer, MASS
- MAU, MAB, Joint Combined Exercise Participants
- CO/XO, Battery, LAAM Bn
- TACC Training Officer
- Combat Experience, Viet Nam

FUNCTIONAL AREA/AGENCY: TAOC

ASSESSMENT LOCATION: MCAS, El Toro

INTERVIEWEE DATA

RANK

One Lieutenant Colonel
One Squadron Leader (RAF)
One First Lieutenant

MILITARY OCCUPATIONAL SPECIALTY

7208/7210

CURRENT BILLETS

- XO, MACG
- Operations Officer, MACG
- TAOC Officer/Senior Air Director, MACS

TOTAL CUMULATIVE USMC EXPERIENCE (YEARS): 40 YEARS

REPRESENTATIVE PAST BILLETS:

- CO, LAAM Bn
- Marine Corps Technical Representative
  Naval Electronics Systems Command
- XO, MASS
- TAOC Operations
- Assistant Operations Officer, MACS
- European Air Defense Operations
- Senior Air Director, MACS
- OIC, MACS Detachment
- MAU, MAB Exercise Participants
- Combat Experience Viet Nam

FUNCTIONAL AREA/AGENCY: FDC

ASSESSMENT LOCATION: MCAGCTC, Twenty-nine Palms

INTERVIEWEE DATA

RANK

One Major
Two Captains

MILITARY OCCUPATIONAL SPECIALTY

0802/5715

CURRENT BILLETS

- S-3A, Field Artillery Group
- CO, Separate Battery
- XO, Separate Battery

TOTAL CUMULATIVE USMC EXPERIENCE (YEARS): 26 YEARS

REPRESENTATIVE PAST BILLETS:

- CO/XO, Battery
- S-3A, Artillery Regt
- Fire Direction Officer
- S-2, Artillery Regt/Bn
- MAU, MAB Exercise Participants
- Viet Nam Combat Experience

FUNCTIONAL AREA/AGENCY: FSCC

ASSESSMENT LOCATION: MCAGCTC, Twenty-nine Palms

INTERVIEWEE DATA

RANK

One Colonel
Two Lieutenant Colonels
One Captain

MILITARY OCCUPATIONAL SPECIALTY

9906/0802/5715

CURRENT BILLETS

- CO, Field Artillery Group
- XO, Field Artillery Group
- G-1, MCAGCTC
- CO, Separate Artillery Battery

TOTAL CUMULATIVE USMC EXPERIENCE (YEARS): 77 YEARS

REPRESENTATIVE PAST BILLETS:

- S-3/S-3A, Artillery Regt
- Assistant Division Fire Support Coordinator
- CO/XO, Artillery Bn/Group
- G-3/G-3A, MAB
- XO, S-3, Infantry Bn
- FSC/FDO, Artillery Regt
- CO/XO, Firing Battery
- MAU, MAB, MAF Exercise Participants
- Viet Nam Combat Experience

FUNCTIONAL AREA/AGENCY: DASC

ASSESSMENT LOCATION: MCAS, El Toro

INTERVIEWEE DATA

RANK

Two Lieutenant Colonels
One Squadron Leader (RAF)
One Captain

MILITARY OCCUPATIONAL SPECIALTY

7208/2502/724/5715/7210

CURRENT BILLETS

- CO, Marine Air Support Squadron
- Assistant Wing CEO
- Assistant Operations Officer, MACG
- DASC Operations Officer

TOTAL CUMULATIVE USMC EXPERIENCE (YEARS): 71 YEARS

REPRESENTATIVE PAST BILLETS:

- Operations Officer, MACG
- Air Control Officer, MAW
- Aviation C^3, MCDEC and HQMC
- CO, MWCS
- MAU, MAB, MAF Exercises
- European Strategic Air Defense
- Combat Experience Viet Nam

FUNCTIONAL AREA/AGENCY: Personnel

ASSESSMENT LOCATION: MCAGCTC, Twenty-nine Palms

INTERVIEWEE DATA

RANK

One Major
Two Captains

MILITARY OCCUPATIONAL SPECIALTY

0802/0180

CURRENT BILLETS

- CO, Separate Artillery Battery
- Adjutant, H&S Bn
- G-1A, MCAGCTC

TOTAL CUMULATIVE USMC EXPERIENCE (YEARS): 47 Years

REPRESENTATIVE PAST BILLETS:

- Action Officer, G-1, FMFPAC
- Adjutant, Marine Barracks, Battalions and Squadrons
- Viet Nam Combat Experience

FUNCTIONAL AREA/AGENCY: Logistics

ASSESSMENT LOCATION: MCAGCTC, Twenty-nine Palms

INTERVIEWEE DATA

RANK

One Lieutenant Colonel
Three Majors
One Captain

MILITARY OCCUPATIONAL SPECIALTY

0302/0802/3002/2102/0430/0402/2110/2340

CURRENT BILLETS

- G-4, Operations Officer, MCAGCTC
- CO, Separate Artillery Battery
- Supply Support Officer, FSSG
- Command Maintenance Management Officer, Force Troops
- S-4, Field Artillery Group

TOTAL CUMULATIVE USMC EXPERIENCE (YEARS): 94 Years

REPRESENTATIVE PAST BILLETS:

- A C/S G-4, Force Troops
- Landing Force Training Command
- XO, Infantry Bn
- CO/XO, Artillery Battery
- S-4, Field Artillery Group
- Group Supply Officer, FSSG
- Supply Officer, Force Troops
- OIC, FSMAO
- CO, LSE
- G-4A, MAB
- OIC, LSU
- Maintenance Officer
- MAU, MAB Exercise Participant
- Viet Nam Combat Experience

FUNCTIONAL AREA/AGENCY: **Intelligence**

ASSESSMENT LOCATION: MCB, Camp Pendleton

INTERVIEWEE DATA

RANK

Two Majors
One First Lieutenant

MILITARY OCCUPATIONAL SPECIALTY

0202/0302

CURRENT BILLETS

- A C/S, G-2, MAF
- A C/S, G-2, MAW
- S-3, MACG

TOTAL CUMULATIVE USMC EXPERIENCE (YEARS): **58 Years**

REPRESENTATIVE PAST BILLETS:

- G-2/S-2, MAF, MAB, MAU
- G-2/S-2, Sqdn, Grp, Wing/Bn-Regt, Div
- LCC and LHA Experience
- Instructor, U.S. Army Intelligence School
- MAF, Division Combat Intelligence Officer
- Joint Staff Intelligence Billets
- G-2, Palm Tree Exercises, READIEX, MAFLEX, etc.
- Interrogation - Translation Teams
- Combat Experience Viet Nam

FUNCTIONAL AREA/AGENCY: MAGTF I

ASSESSMENT LOCATION: MCB, Camp Pendleton

INTERVIEWEE DATA

RANK

Five Colonels

MILITARY OCCUPATIONAL SPECIALTY

9906/9907/0302/2502

CURRENT BILLETS

- C/S, Marine Amphibious Force
- Division/Wing Communication - Electronics Officer
- CO, Marine Air Control Group
- CO, Marine Air Group

TOTAL CUMULATIVE USMC EXPERIENCE (YEARS): 146 Years

REPRESENTATIVE PAST BILLETS:

- C/S, Marine Division
- Division Operations Officer
- CO, Marine Amphibious Unit
- C/S, Marine Amphibious Brigade
- Division Intelligence Officer
- Chief, Command, Control, Communications Division, M.C. Development Center
- Chief, Communications - Electronics Branch, HQMC
- CO, Marine Air Control Squadron
- Operations Officer, MACG
- CO, Marine Corps Communications-Electronics School
- Divsion Air Officer (FSCC)
- MAU, MAB, MAF Exercise Participants
- Combat Experience Korea and Viet Nam

FUNCTIONAL AREA/AGENCY: **MAGTF II**

ASSESSMENT LOCATION: MCAGCTC, Twenty-nine Palms

INTERVIEWEE DATA

RANK

One Colonel
Three Lieutenant Colonels
Two Majors

MILITARY OCCUPATIONAL SPECIALTY

0107/0302/0430/0802/1802/7210/7208/9906

CURRENT BILLETS:

- CO, Field Artillery Group
- XO, Infantry Battalion
- Staff Officers, Tactical Exercise Control Center, MCAGCTC

TOTAL CUMULATIVE USMC EXPERIENCE (YEARS): **134 YEARS**

REPRESENTATIVE PAST BILLETS:

- S-3 Artillery Regiment
- Division Fire Support Coordinator
- CO/XO Artillery Bn
- G-3 MAB
- CO/XO/S-3/S-4 Infantry Bn
- S-3 Infantry Regiment
- Division Air Observation Officer
- CO/S-3 Tank Bn
- G-3 Marine Division
- S-3 MASS
- Air Defense Control Officer, MACS

APPENDIX F

Numerical Calculations

This appendix explains the basis for combining the within-area assessments with the across-area assessments to obtain a unified scale of benefits. In addition, the assumptions and calculations used to obtain the ranges of estimates are presented.

The within-area assessments give the value of improving tasks as a percentage of the value of direct improvements to the operational area. Once the relative values of direct improvements to the operational areas are known, it is possible to compare the values of improvements to tasks from different areas. One approach for obtaining the relative values of direct operational area improvements is direct assessment through making the following comparison: Which is more important to Marine Corps MAGTF, that part of an improvement in COC functions which helps COC or that part of an improvement in Intelligence which helps Intelligence? An easier approach compares the value of direct and secondary benefits.

Assuming that the value to a MAGTF of an improvement to any operational area is the sum of the value of the direct improvement to that operational area and the value of the secondary improvements to other operational areas, the two approaches are related by the matrix equation:

$B = VW$ where

B_i = total benefit to MAGTF of an improvement in operational area i,

V_{ij} = value to operational area j of an improvement in operational area i,

and W_i = weighting factors reflecting the relative value to a MAGTF of direct benefits to operational area i.

The columns of V are the operational area scales discussed in Section 3.3. Given V, the matrix equation can be solved if either B or W is known. The first approach discussed above for getting a unified scale directly assessed W and then calculated B. The second approach--and the one used—assesses B and calculates $W = V^{-1}B$.

Combining the nine operational area scales gives the matrix in Table F-1. This matrix has only 7 rows because in developing the operational area scales, FDC, FSCC, and DASC were combined into one operational area. At the MAGTF session the relative values of improvements to FDC, FSCC, and DASC were assessed at 10, 50, and 40, respectively. Using these weights, the three operational area scales are combined into one scale, reducing the matrix to 7 columns.

Inverting this matrix and multiplying by B gives the values for W shown in Table F-2.

Multiplying the columns of V by the corresponding elements of W distributes the total benefits as shown in Table F-3. Summing across any row gives the total benefit of improvements to an operational area. Summing down any column gives the benefit received by each operational area if all the areas were improved. Since a direct benefit is the value to an operational area of an improvement in that area, direct benefits can be read directly from Table F-3.

Direct benefits are allocated to task categories by multiplying the direct benefit for an operational area times the relative weights for each task in that operational area. Secondary benefits are allocated to task categories by assuming that the relative weights for tasks are the same as those for direct benefits. This assumption implies that if the improvement in task COC A is worth 50 percent of the direct COC benefits, that it would also be worth 50 percent of all secondary benefits. One result of this assumption is that the total benefits can be allocated to task categories by multiplying total benefits from an improvement to an operational area times the weights of the tasks in that area. This assumption is used to calculate the integrated task benefit list in Appendix G.

Ranges on benefits are obtained through both direct assessment and calculations. Two MAGTF sessions provided direct assessment of total benefits. As explained in the text, the Camp Pendleton assessments are taken as the best estimate with the Twenty-nine Palms assessments being used for the range estimates. In addition, a set of assessments obtained before the end of the day at the Camp Pendleton session are used in the range estimates.

It has been assumed that the MAGTF assessments include both direct and secondary benefits. Discussions at these sessions indicated that, in fact, the officers did include some secondary benefits in their assessments. A worst case assumption would be that only direct benefits were included, implying that W, and not B, was assessed. Multiplying this assessed W by the matrix V gives a calculated B which is used in the range estimate.

Table F-1

Operational Area Scales Matrix

Improvement in \ Value to	COC	TACC	TAOC	FDC	FSCC	DASC	Per	Log	Intel
COC	100	15	0	0	7	0	0	8	5
TACC	3	100	32	0	0	8	0	0	.7
TAOC	0	15	100	0	0	0	0	0	0
FDC/FSCC/DASC	23	20	32	100	100	100	0	0	10
Per	0	.5	0	0	0	0	100	0	0
Log	3	5	0	6	0	0	0	100	0
Intel	15	11	16	7	3	0	0	0	100

Table F-2

Weighting Factors for Direct Benefits

W_{CAC}	.061
W_{TACC}	.080
W_{TAOC}	.20
$W_{FDC/FSCC/DASC}$	.34
W_{Per}	.0066
W_{Log}	.024
W_{Intel}	.012

Table F-3

Benefit from Improvements to Operational Areas

Improvement in \ Value to	COC	TACC	TAOC	FDC	FSCC	DASC	Log	Per	Intel	SUM
COC	6.1	1.2	0	0	1.14	0	0	.2	.06	8.7
TACC	.2	8.2	6.5	0	0	1.1	0	0	.01	16
TAOC	0	1.2	19.8	0	0	0	0	0	0	21
FDC/FSCC/DASC	1.4	1.7	6.4	3.4	17	14	0	0	.12	44
Per	0	.04	0	0	0	0	.7	0	0	.7
Log	.1	.4	0	.2	0	0	0	2.4	0	3.1
Intel	.9	.9	3.2	.2	.6	0	0	0	1.2	7.0
SUM	8.7	13.6	35.9	3.8	18.7	15.1	.7	2.6	1.4	100.5*

* The numbers do not sum to 100 due to round-off error.

APPENDIX G

Relative Benefit from MTACC System Improvements to Operational Area Tasks

TASK			
TAOC	B	Detect/Identify/Display	9.24
DASC	D	Monitor and Coordinate DAS	8.40
FSCC	E	Monitor and Coordinate	7.81
FSCC	D	Target Information	7.14
DASC	B	Immediate DAS	6.28
COC	A	Operations Planning	4.55
TAOC	C	EW	4.24
Intel	D	Receive/Record	3.86
TACC	F	Aircraft Management and Allocation	3.82
TAOC	A	Plan for and Engage Enemy Air Threats	3.82
TACC	H	FRAG	3.76
COC	B/C	Supervise/Integrate Fire Support	3.75
FSCC	B	Fire and Air Support Plans	3.42
FSCC	C	Restrictive and Control Measures	2.97
Intel	G	Disseminate	2.47
TACC	G	Divert	2.38
TAOC	E	Air Traffic Control	2.23
DASC	E	Air Defense Coordination (FAAD)	2.00
TACC	D	Monitor and Supervise	1.74
Log	A	G-4/S-4	1.68
TACC	C	EMCON Conditions	1.59
TACC	I	MAG/Squadron Operations	1.19
TAOC	F	TACC Backup	1.06
FDC	G	Fire Missions	.94
FDC	F	Target Information	.83
FDC	B	Artillery Fire Plans	.80
FDC	A	Nuclear/Chemical Fire Plans	.79

TASK

FDC	E	Fire Unit Status	.74
DASC	A	Preplanned DAS	.74
Log	B	Supply Operations	.73
FSCC	A	Supporting Arms Requirements	.46
TACC	A	Alert Conditions	.43
TACC	E	Information Dissemination	.41
Log	C	Maintenance Operations	.40
TAOC	D	Track Information Exchange	.38
TACC	B	Air Defense Zones of Action	.36
Per	G	Personnel Administration	.33
Intel	E	Initial Processing	.31
Log	E	Transportation	.21
FDC	C	Ground Situation Information	.18
COC	F	Tactical Alerts	.16
COC	D	Allocate Assets	.16
Per	F	General Correspondence and Reports	.15
Intel	A	Determine Requirements	.15
Intel	F	Interpret	.15
FDC	D	Damage Assessment	.13
Per	H	Classified Material Control	.12
DASC	C	BDA/Intelligence	.06
COC	G	Coordinate with Adjacent Units	.06
Log	D	Evacuation and Hospitalization	.06
Per	D	Morale and Personnel Services	.05
Intel	C	Supervise Collection	.04
DASC	F	ASRT Targeting	.03
Intel	B	Collection Planning	.02
COC	E	Operational Reports	.02
Per	C	Graves Registration	.02
Per	A	Strengths and Replacements	.01
Per	B	Prisoners of Wars	.01
Log	F	Services	.01
Per	E	Civilian Employees	.00